Transformation of Geographical Information into Linguistic Sentences: Two Case Studies

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Information can be communicated at three levels, i.e., the syntactic, the semantic and the pragmatic level. Since the pragmatic level is related to the application of the data, transformation of information from the lower level representations to the pragmatic level can reduce the amount of information to be processed by the receiver and speed up the perception of the information. For example, assume a display showing a submarines position relative the terrain surface. Since the distance along six axes must be evaluated, i.e., ahead, backwards, port, starboard, up and down, the presentation of the numerical values along the axes must be carefully designed in order to communicate the information unambiguous to a human operator. The first part of the present paper shows how fuzzy logic can be used to design the kind of instrument considered. The second part of the paper shows how the zone of safety around the submarine, the uncertainties of the terrain model and the submarines position can be modelled as fuzzy regions and how the topological relations between this kind of regions can be described in natural language sentences.

Based on a perception study we found that the perception of "long distance" is related to the frame of the map. The experiment did show that people associate the term "long distance" to two points when the distance between them is 40% of their maximal distance in the display. From this experiment we have designed an instrument to communicate the degree of risk so that a bar gets length 40% of its maximal length when the risk is on the boarder between low and high. From the knowledge of the speed of the submarine and the tactical assessments the degree of risk is modelled as a fuzzy membership function. In that way the distance from the vessel to the terrain surface can be visualized as the degree of risk along the six axes considered. The distance corresponding to the boarder between low and high risk is marked by its numerical value at the 0.4 level of the risk bar.

The second part of the paper describes a method to generate natural language statements about topological relations between fuzzy regions. The methodology, which relies on the fuzzy 4-intersection, is a generalization of the crisp 4-intersection of Egenhofer and co-workers. From the computation of the similarity between the fuzzy- and the crisp 4-intersection the natural language statement, i.e., the linguistic variable, is derived. The linguistic variable contains a semantic part which gives an immediate association to a crisp relation and a quantifier which indicates the strength of the relation. Since the derivation of the linguistic variable depends on the definition of the boundary of the fuzzy regions, a method to compute fuzzy boundaries is presented. A simulation experiment demonstrates the properties of the proposed methodology, and it shows how the linguistic variable relates to an inclusion index. An example illustrates how some level of action can be associated to the linguistic variable, which is applicable in course control of moving crafts, in military applications or in other kinds of operations where the level of warning or action depends on the topological relation between the fuzzy regions.

Since processing spatial information often entails dealing with features which are inexact in some sense, the problem of dealing with non-exact objects or classes is of considerable practical importance in geographical information systems (GIS). Despite that the phenomenon of the real world often are non-

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exact, the crisp model is widely used in GIS. The limitation imposed by the crisp model or the two-valued logic is recognized in geographical information and several other disciplines like soil science and engineering, in areas of application like object-oriented databases, and data mining. In the literature there are several attempts at defining topological relations between non-exact regions, i.e., fuzzy regions. The difficulty in the extension of the crisp topology to the fuzzy case lies in how to pick out the suitable generalization from the large number of approaches. Imagine some kind of field operation. Due to some tactical assessment, for example in a military operation, the area of interest is assumed to be classified according to its accessibility. If we apply the crisp model and classify the different parts of the area as accessible or not, we can imagine the difficulty in drawing the line between the two classes. In some cases there may be regions which clearly not belong to the one or the other group. If we introduce the degree of accessibility, i.e., we apply the fuzzy model, we can make finer distinctions between the different parts of the area. Let us extend the example and assume that we have a moving craft and a security zone around it. The craft and its zone can be modelled as a fuzzy region B with the membership in B decreasing from 1 to 0 as the distance from the craft increases. The membership function can take different parameters as arguments like the speed of the craft, the accuracy of its computed position and the distance from the craft. Let us assume that B is moving towards fuzzy region area A. First we assume that the relation between B and A can be characterized as "B and A are clearly disjoint." As B moves closer to A, the relation gradually changes from disjoint to inside. How the topological relation between B and A changes from "clearly outside" to "clearly inside" is the topic for this paper. A novel idea to model this kind of relations between spatial features is presented. The method applies the bi-combination of the five natural language terms (1) disjoint, (2) touch, (3) overlap, (4) inside, and (5) covers. By the application of qualifiers like clearly, mostly, somewhat and slightly the topological relations between two fuzzy regions can be described as (clearly disjoint), (somewhat disjoint/slightly touch), or (mostly inside/somewhat overlap). The method for the derivation of the linguistic descriptions is founded on a similarity computation to the Egenhofer 4-intersection model.

SYMPOSIA DISCUSSION – PAPER NO: 18

Author's Name: Dr. Jan Terje Bjørke, FFI, Norway

Comment:
Cognitive behavior is specific to an individual, since people interpret displays in different ways. It will be important when developing tools to select the people with the abilities to interpret the displays correctly.

Question:
Were computer games tried out as a measurement and guideline for the design?

Author's Response:
No but it could be useful.

Comment:
Consider adding the dimension of stress and utility. If an analog domain is mapped into discrete symbols the user will recreate the analog situation in their mind. Each user may impose biases on the interpretation of the symbols and will also be influenced by the stress level at the time.

Comment:
It may be beneficial to add a complementary display. Include the safety factor in addition to the risk factor. Indicate the right way to go, not just the wrong way.

Transformation of geographical information into linguistic sentences: Two case studies

Jan Terje Bjørke

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Overview

- Levels of communication
- Information reduction, the application of BLOBs
- Fuzzy BLOBs
- The description of topological relations between fuzzy BLOBs
- A travel: The sea floor seen from a submarine
- The design of navigation instruments based on risk factor computation
- The description of the risk factor in natural language
- Conclusions

Communication levels

- **Syntactic level: low level information, i.e., the map symbols or the words,**
- **e.g.: S=1000m.**

- **Semantic level: the meaning of the map symbols,**
- **e.g.: the distance from A to B is one thousand meters.**

- **Pragmatic level: the application of the map information, i.e., the meaning of the map symbols related to a certain application.**
- **e.g.: the distance from A to B is rather short.**

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CASE 1: Fuzzy BLOBs and fuzzy regions

Channel capacity

Useful information = Entropy – Equivocation

The channel capacity C is defined as:

C=max(R)   where   R= H(y)-H(Y|X)

Entropy

$$H(Y) = \sum_{y \in Y} p(y) \log_2 (1/p(y)) = -\sum_{y \in Y} p(y) \log_2 p(y)$$

where $1/p(y)$ **is a measure of the amount of information.**

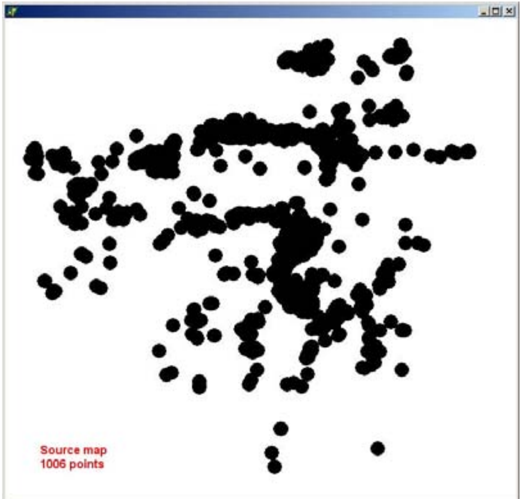
Equivocation

$$H(Y \mid X) = -\sum_{x \in X} p(x) \sum_{y \in Y} p(y \mid x) \log_2 p(y \mid x)$$

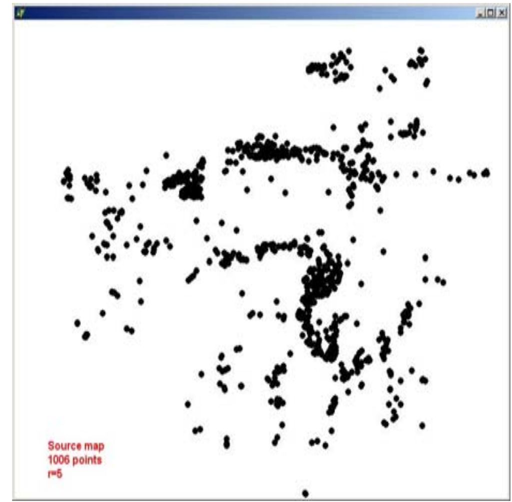
where $p(y \mid x)$ **is the conditional probability that symbol x is interpreted as symbol y.**

Optimize the communication at the syntactic level by eliminating conflicting map elements

Dot size r=10

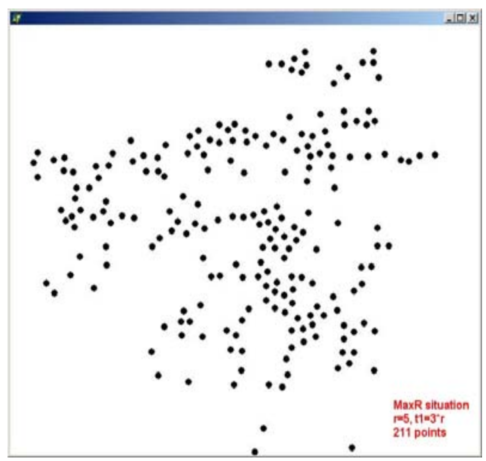


Dot size r=5

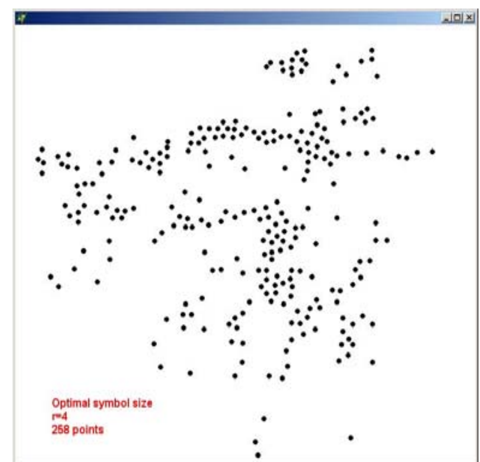


Max R, when r=10

Max R, when r=5



Max R when r=
optimal symbol size



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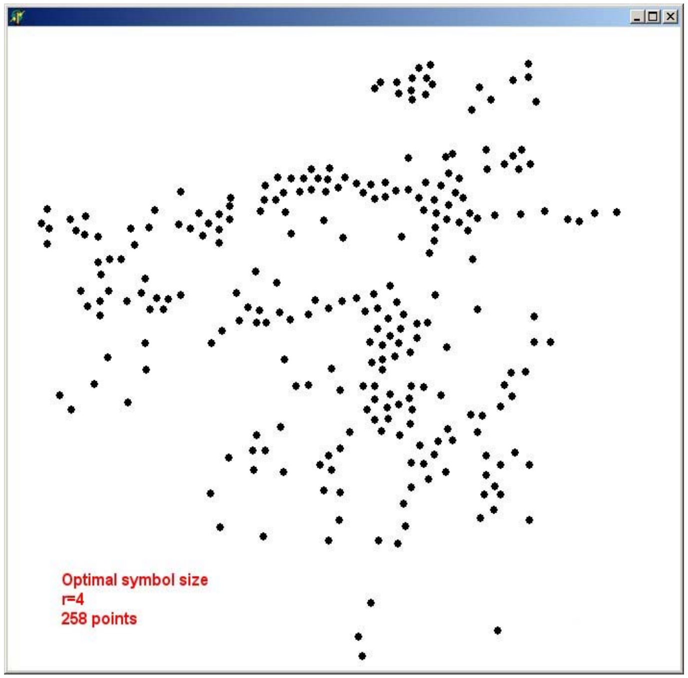
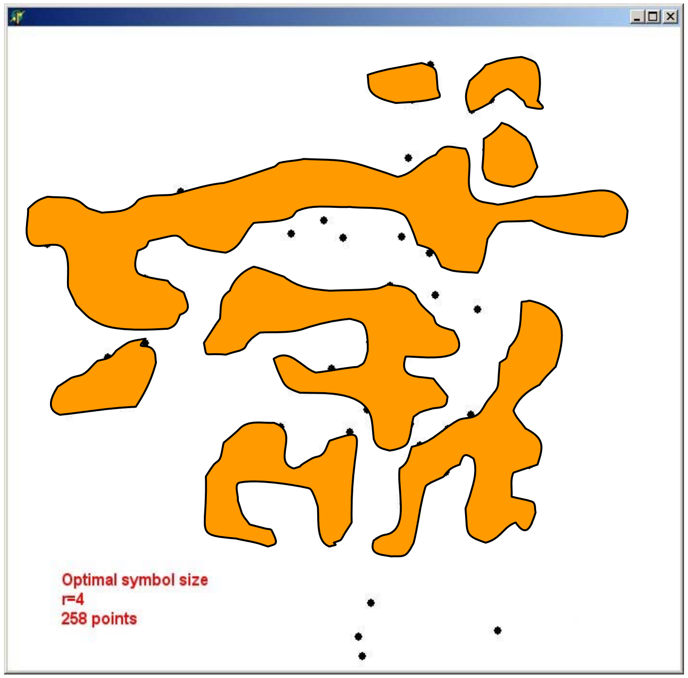
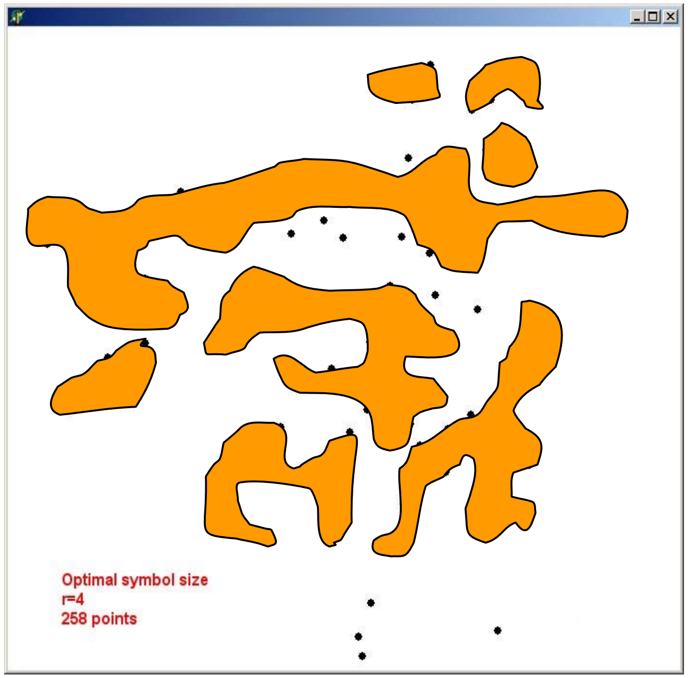
Group elements, i.e., create BLOBs (Wright and Kapler): Move the information to a higher level of abstraction





Crisp or fuzzy BLOBs

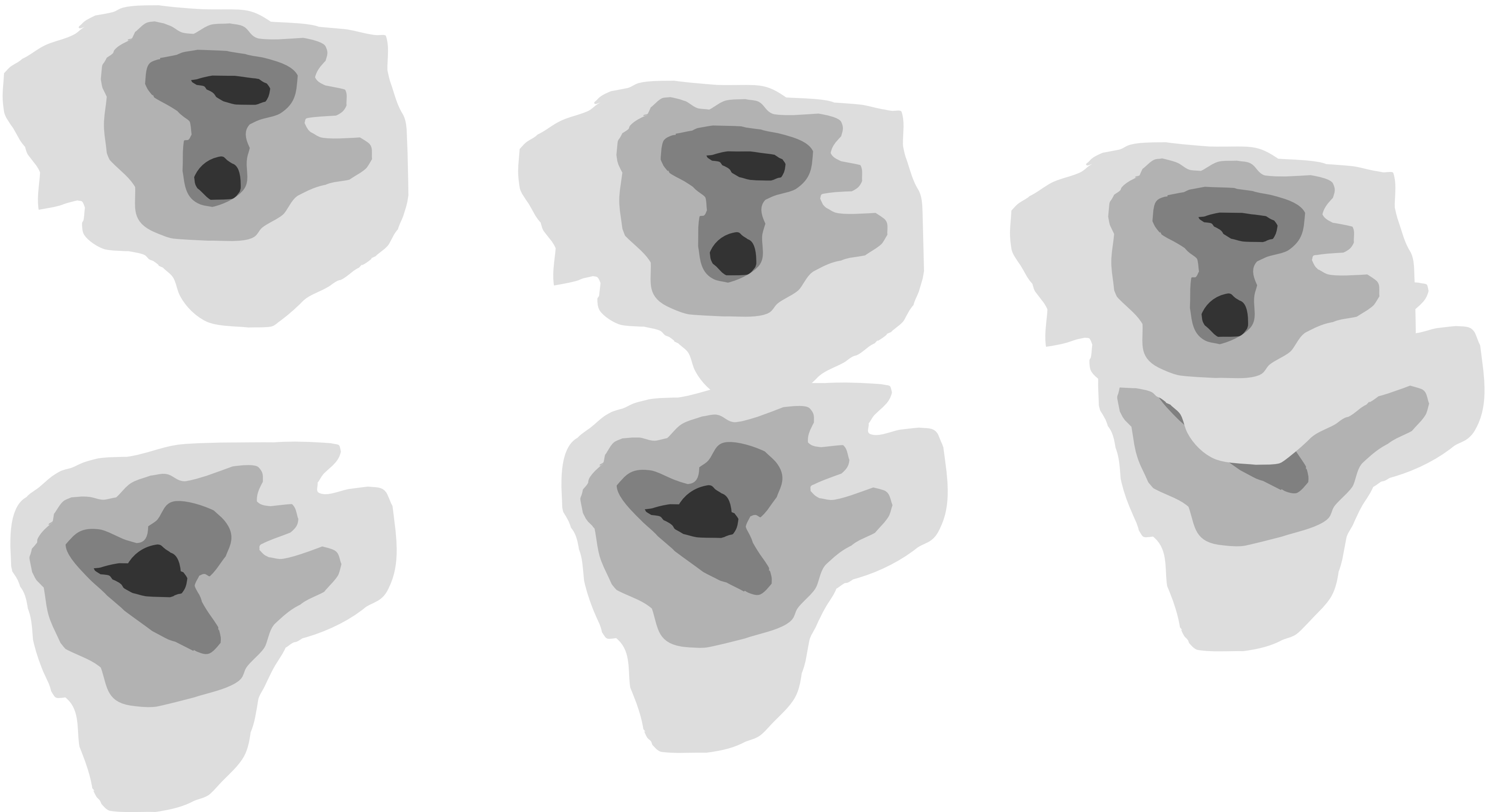
Crisp BLOB



Fuzzy BLOB

Fuzzy BLOB

How to visualize the topological relation between fuzzy regions



How to talk about topological relations between fuzzy BLOBs?

- Disjoint
- Disjoint touch
- Touch disjoint
- Touch
- Touch overlap
- Overlap touch
- Overlap
- Overlap inside
- Inside overlap
- Inside

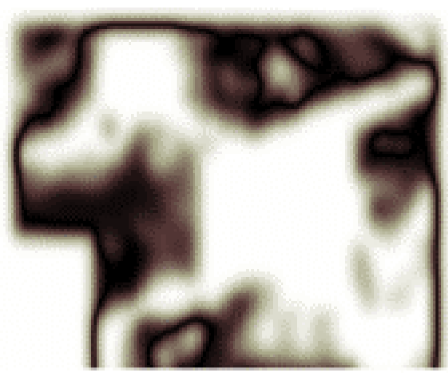
Computation of topological relations between fuzzy regions

- The computation is based on the similarity to the crisp 4-intersection
- This requires a definition of:
  - fuzzy interior
  - fuzzy boundary
  - concept for the similarity computation. This concept can be based on union and intersection operators for fuzzy sets.

A fuzzy region and its boundary

Fuzzy region $\mathcal{A}$

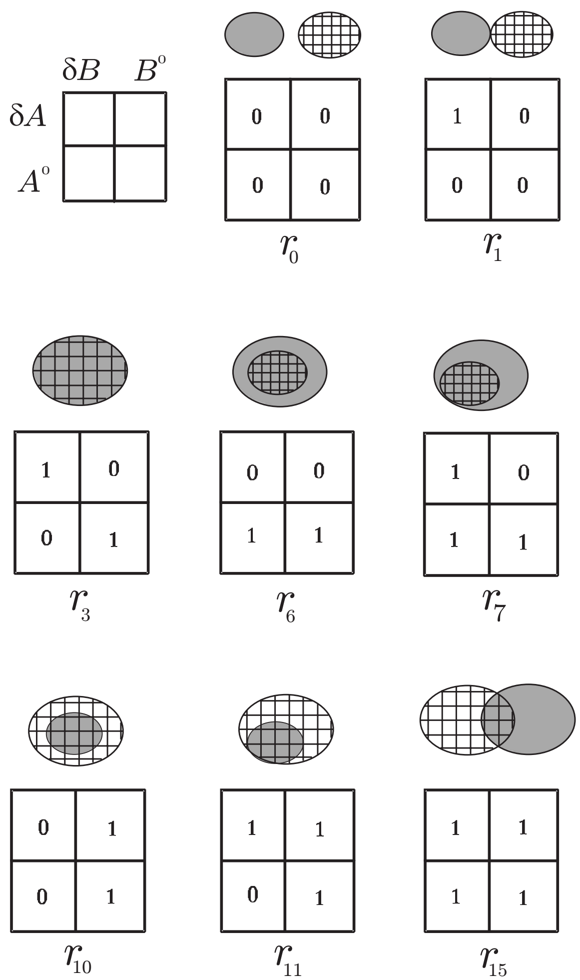
A fuzzy region



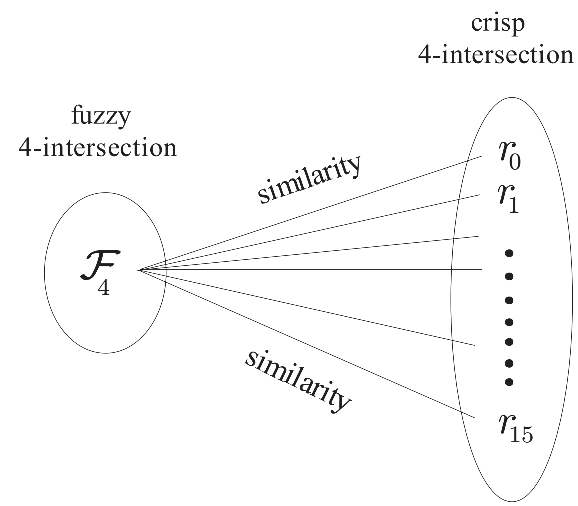
Its boundary

Fuzzy boundary of $\mathcal{A}$

The crisp 4-intersection



The fuzzy 4-intersection



Definition of topological properties of fuzzy regions

- **Fuzzy region A is defined by its membership function as:**

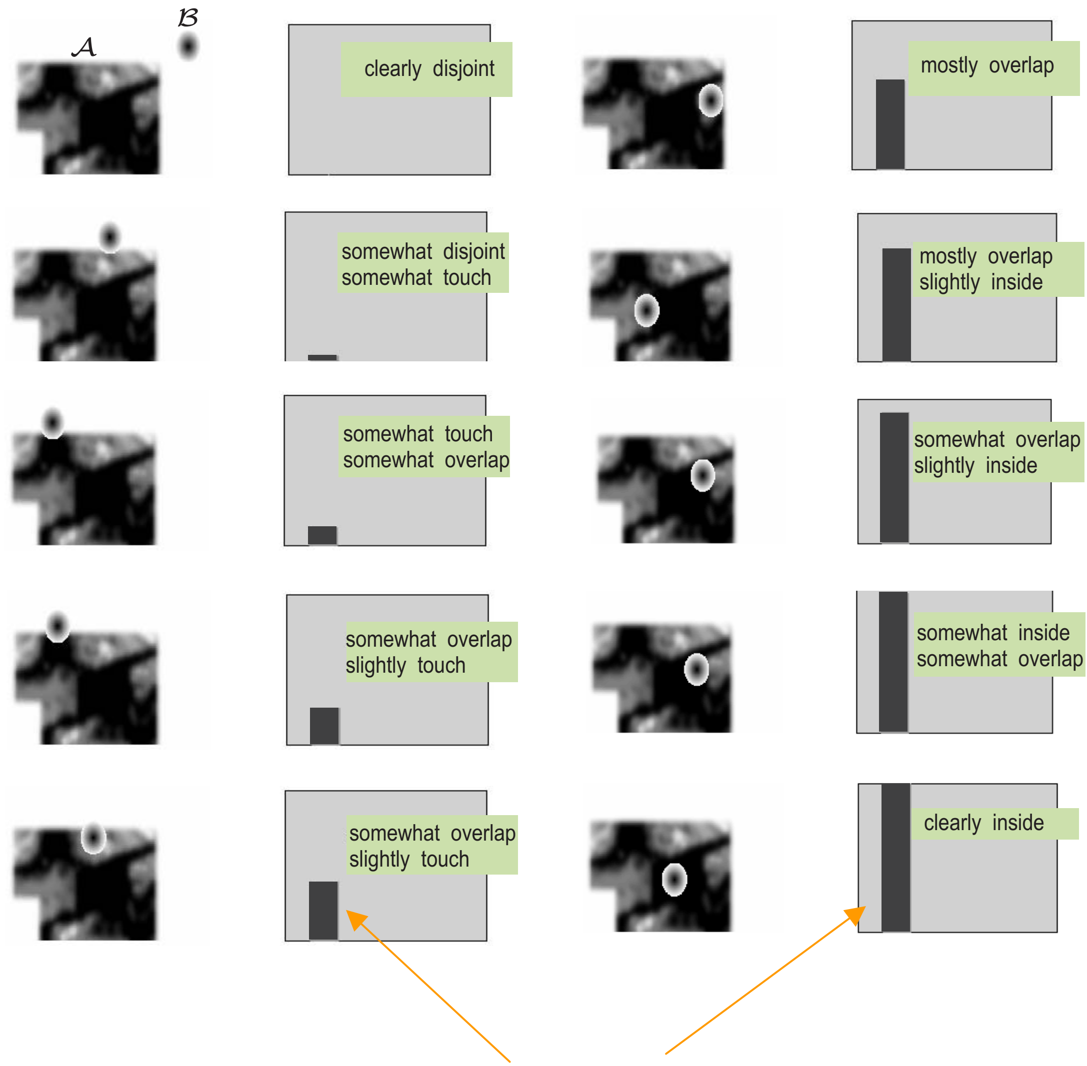
$$u_A(x, y)$$

- **The interior of A is defined as:**

$$u_{A^0}(x, y) = u_A(x, y)$$

- **The boundary of A is defined so it has its maximum membership value for points wich are midway between the exterior, i.e. the complement, and the interior of A.**

$$
\begin{aligned}
&\text{if} \quad u_A(x, y) > 0.5 \\
&\quad u_{\partial A}(x, y) = 2(1 - u_A(x, y)) \\
&\text{else} \\
&\quad u_{\partial A}(x, y) = 2u_A(x, y) \\
&\text{end}
\end{aligned}
$$

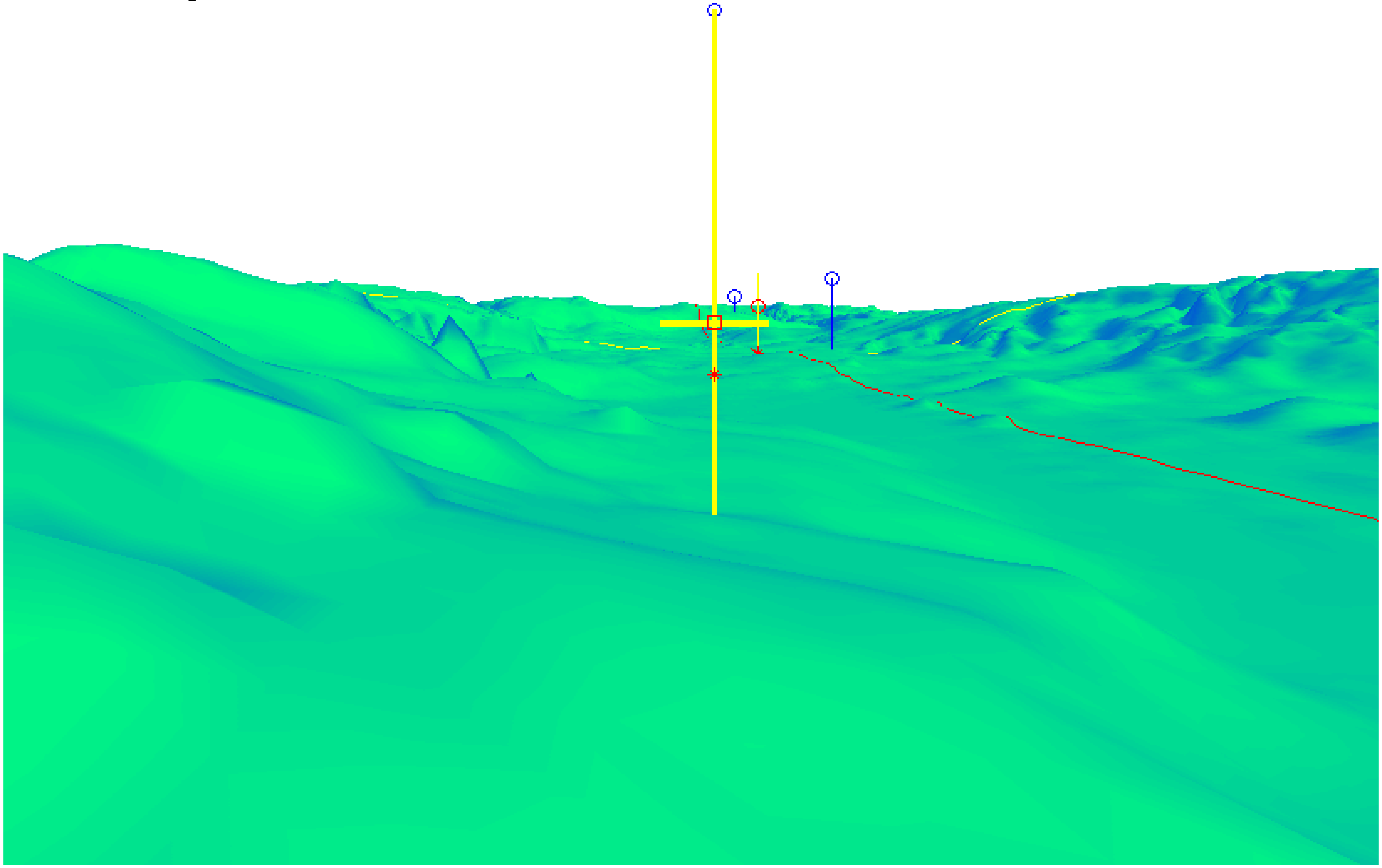


Inclusion index

Demonstration of linguistic descriptions of topological relations between fuzzy regions

CASE 2: Navigation of a submarine

Perspective view



Risk factor

- Apply natural language sentences as:
- the risk is low;
- the risk is high;
- the risk is very high.

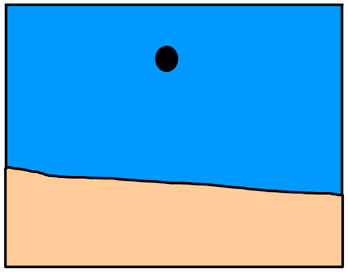
- Natural language has many dialects, multiple representation;
- Goal: find an iconic representation which is close to the natural language statements considered.

Perception of distance

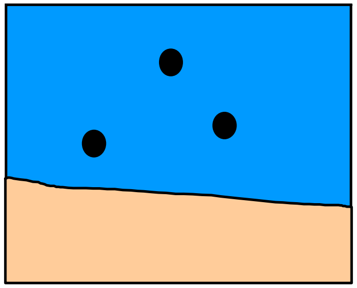
- The perception of distance is investigated among 40 subjects. Each of them was asked to evaluate the propositions:
- the distance is large
- the distance is small
- Several maps were designed. The maps were presented on a 20 inc. screen in a window of two kinds of size.
- Size of window 1: 30 x 20 cm.
- Size of window 2: 40 x 30 cm.

The test plates

One point symbol in each window

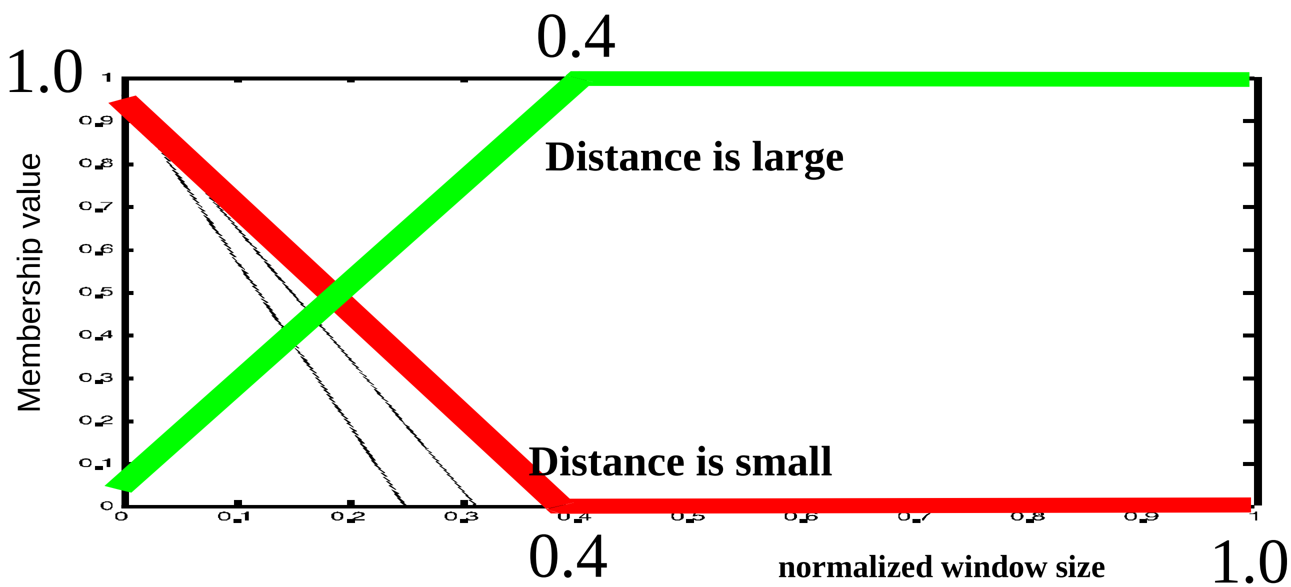


Several point symbols in each window

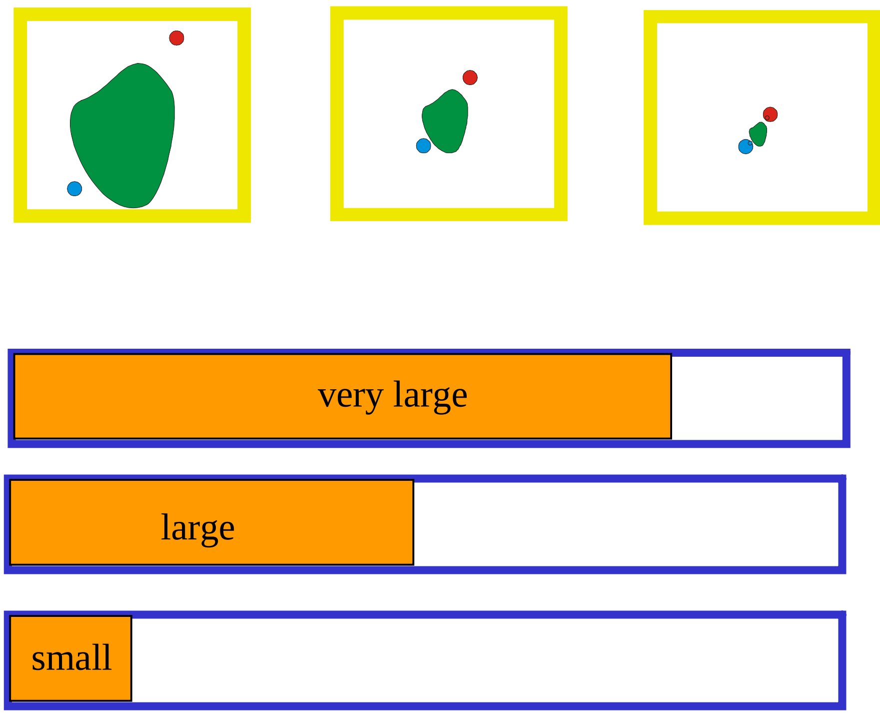


The subjects were asked to evaluate the distance from a certain circle to the shore line

The two propositions distance is large / short come out as complementary statements



The scale effect

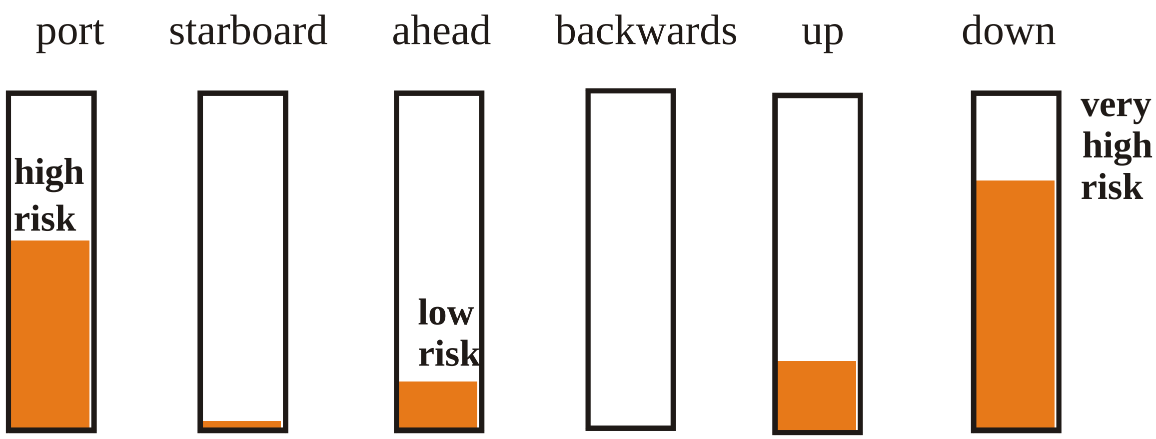


- The effect that the interpretation of the distance between the map symbols depends on a relation between the bounding frame and the map scale, is termed the scale effect.

- The scale effect can be utilized in the design of instruments.

The navigation intruments

6 axis:

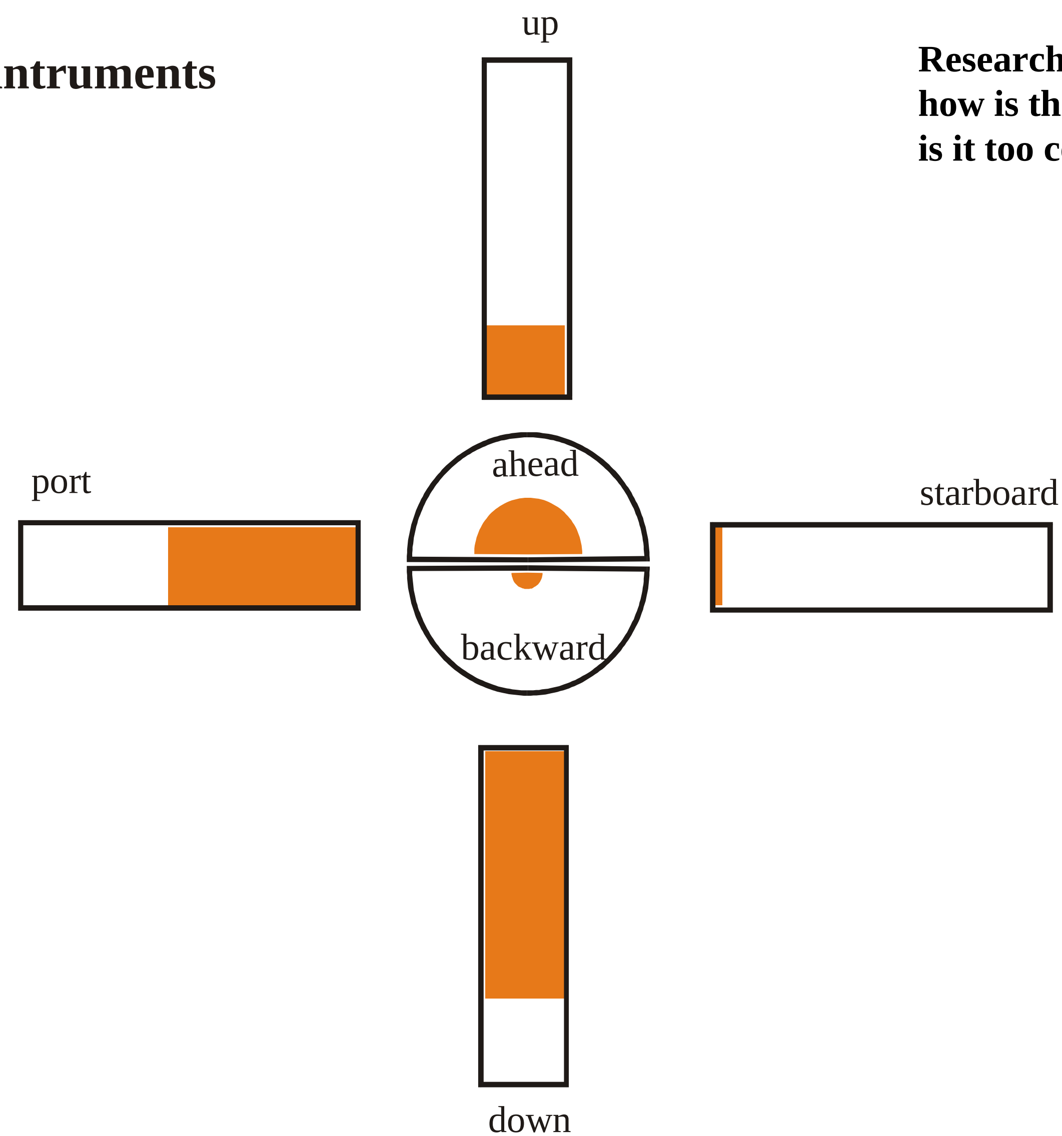


Metrical information can be turned on

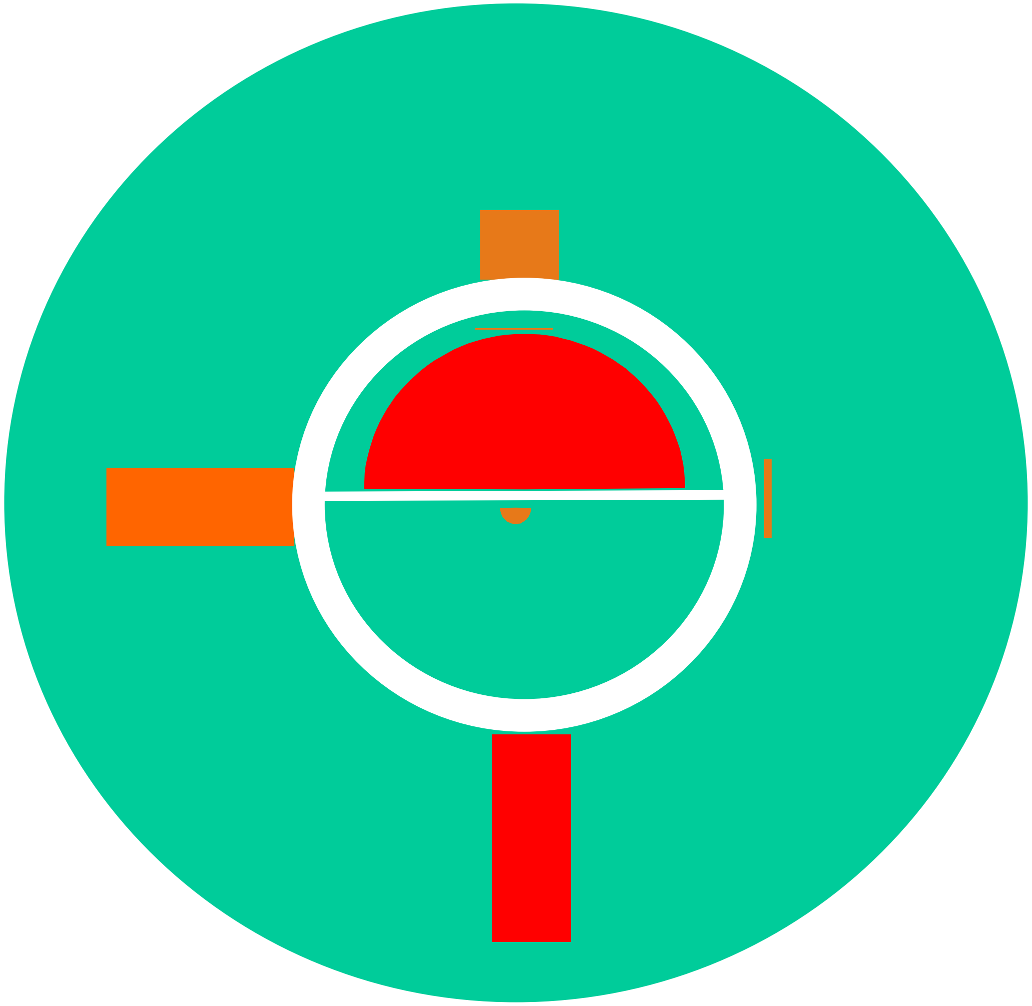
When the metrical information is turned on, the instrument shows both the degree of risk and the distance to the terrain surface. The scale is selected so that the yellow bar has a length 40% of its maximal length when the risk is on the boarder between high and low.

The navigation intruments

Research questions:
how is this instrument perceived?
is it too complex?



The navigation intruments: Design 2



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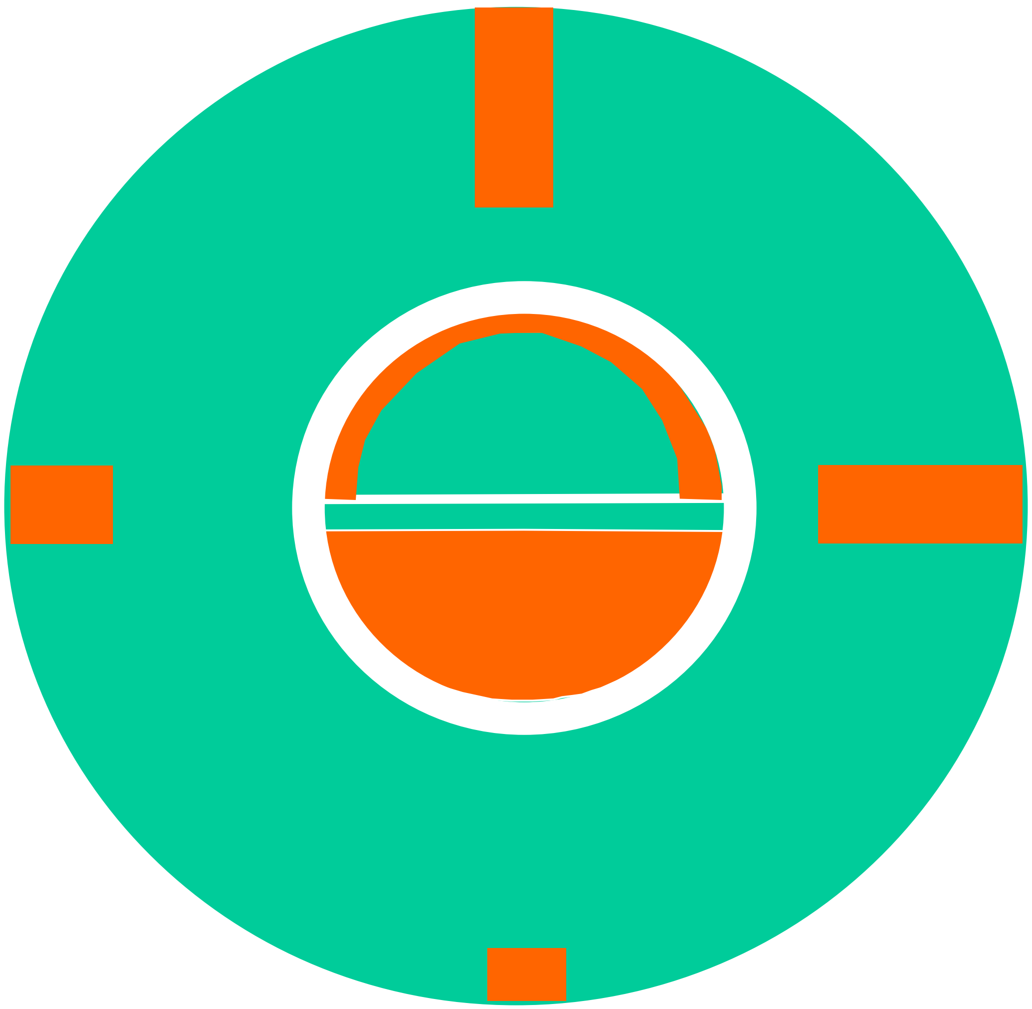
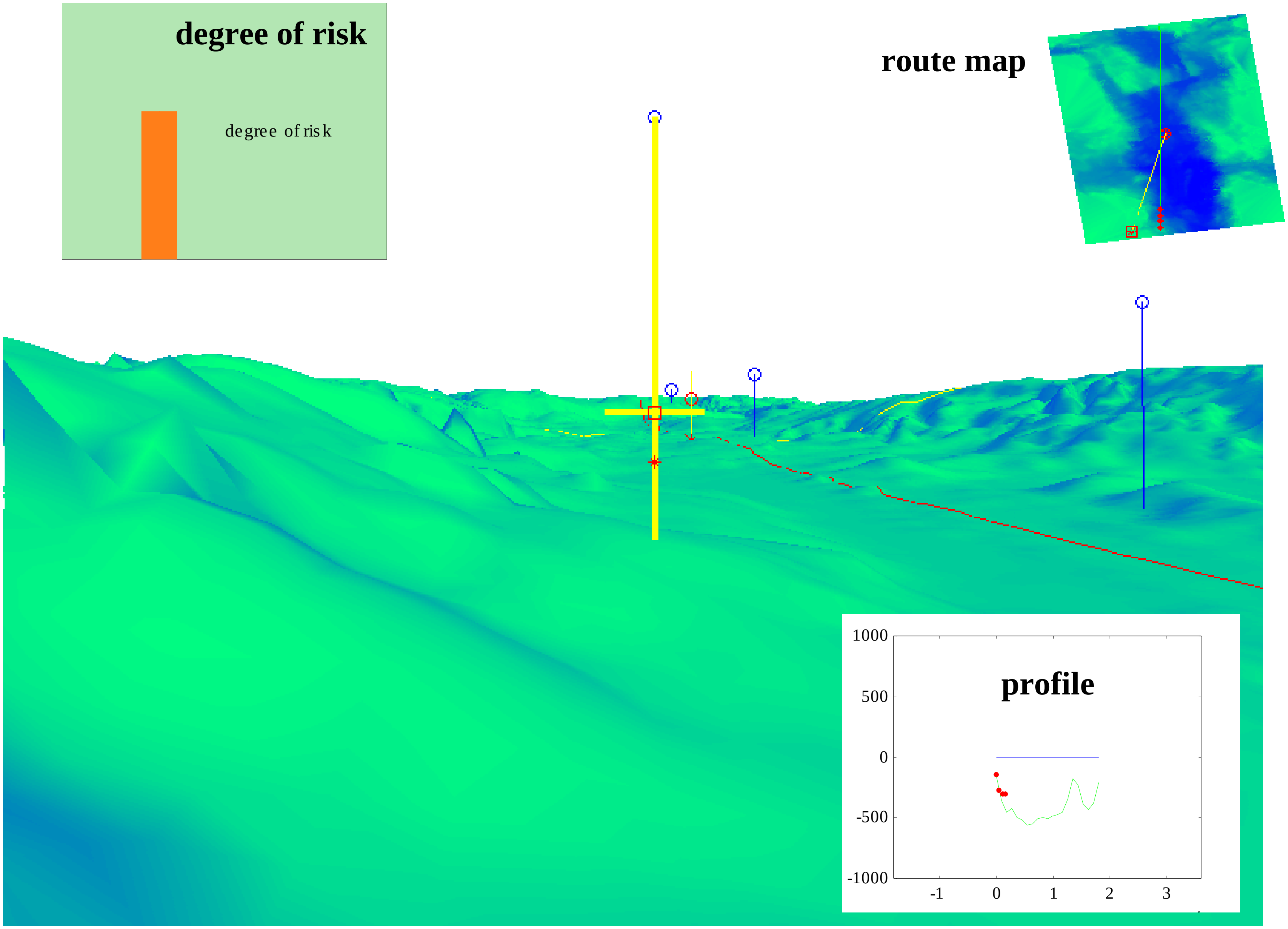
The navigation intruments: Complement design



Simulation of a travel in the terrain model

- The next views simulate a travel in the terrain model.
- They illustrate the problem of visualizing how safe the vessel rout is.


degree of risk
degree of risk
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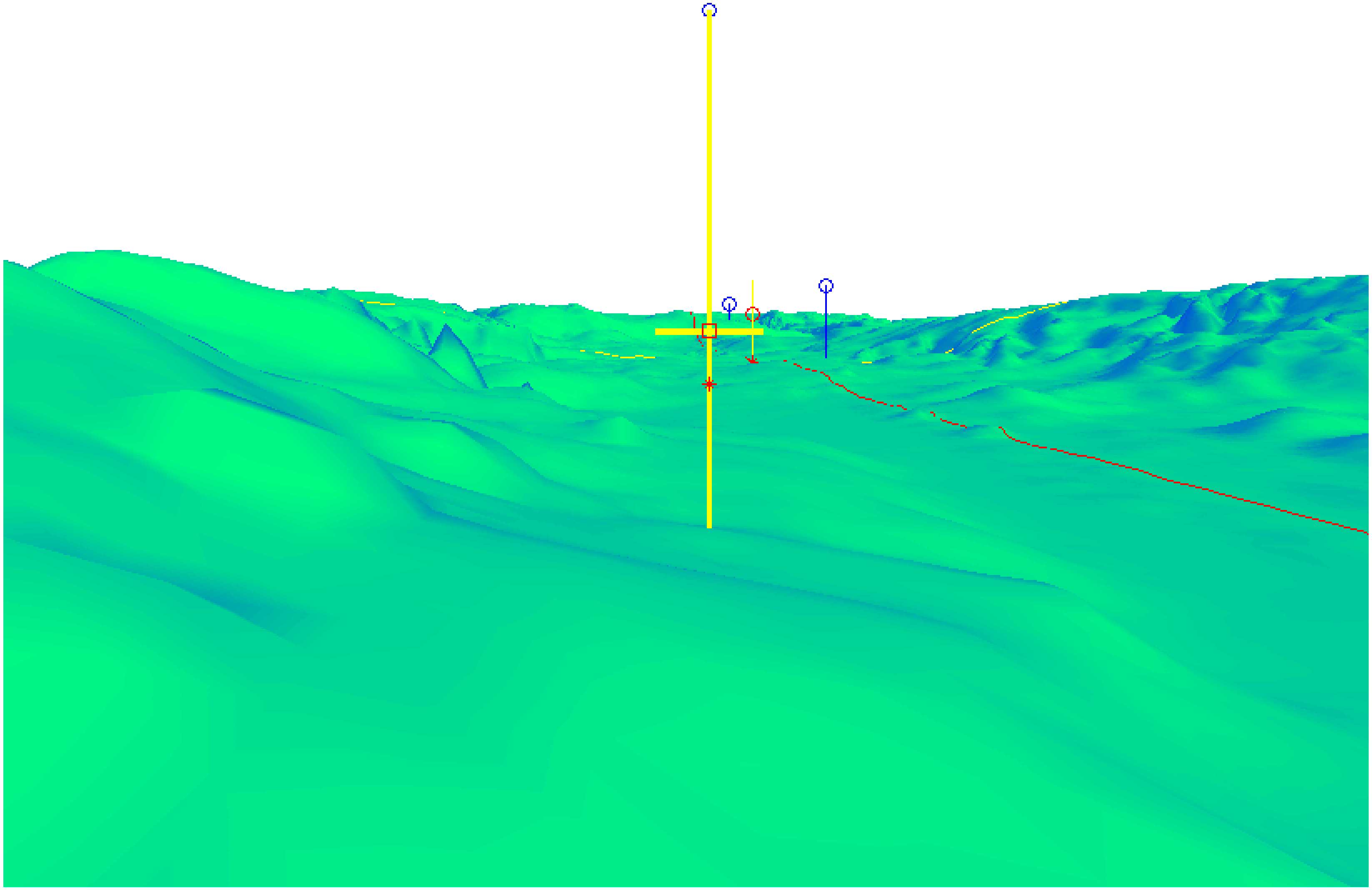

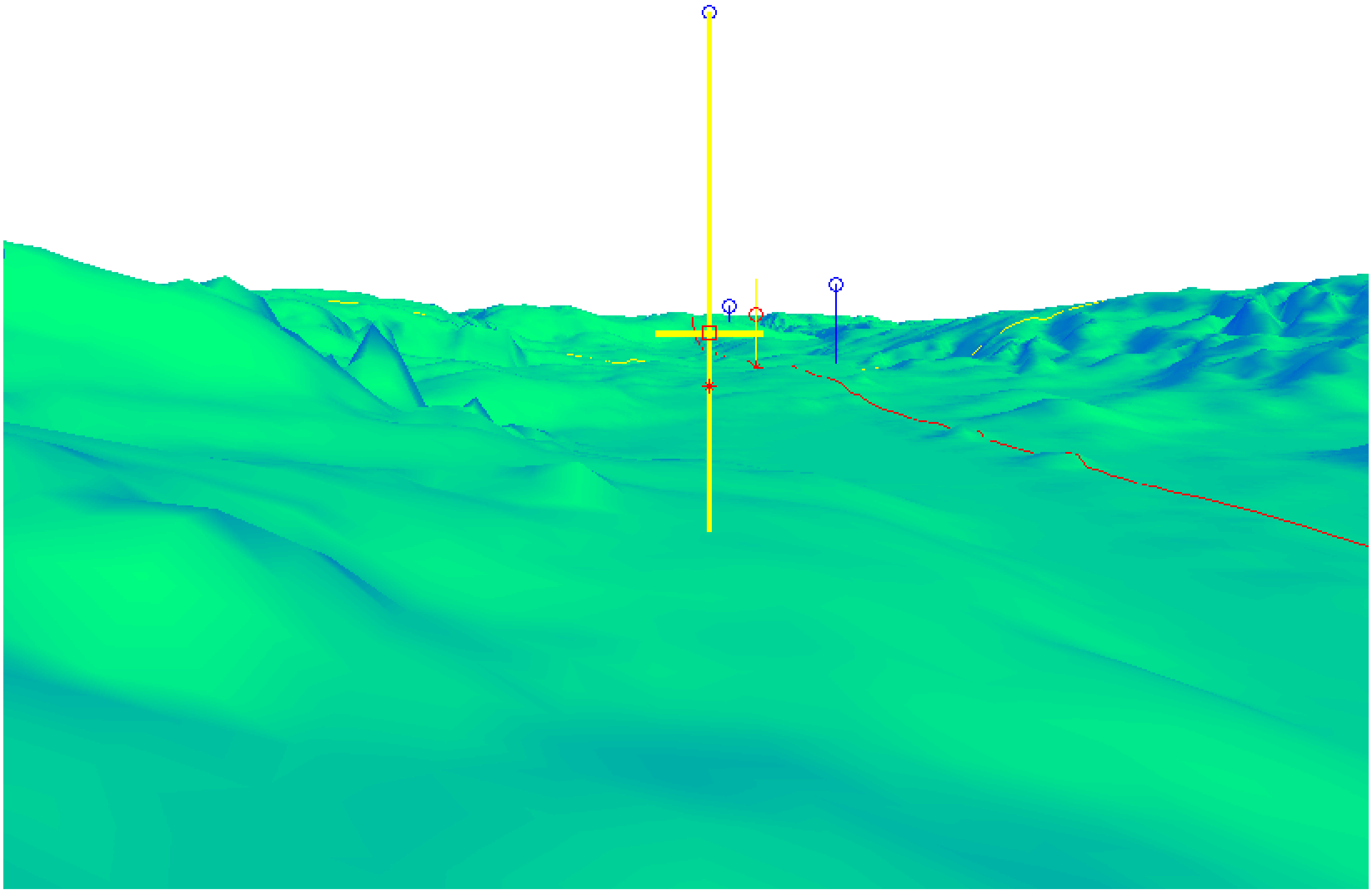

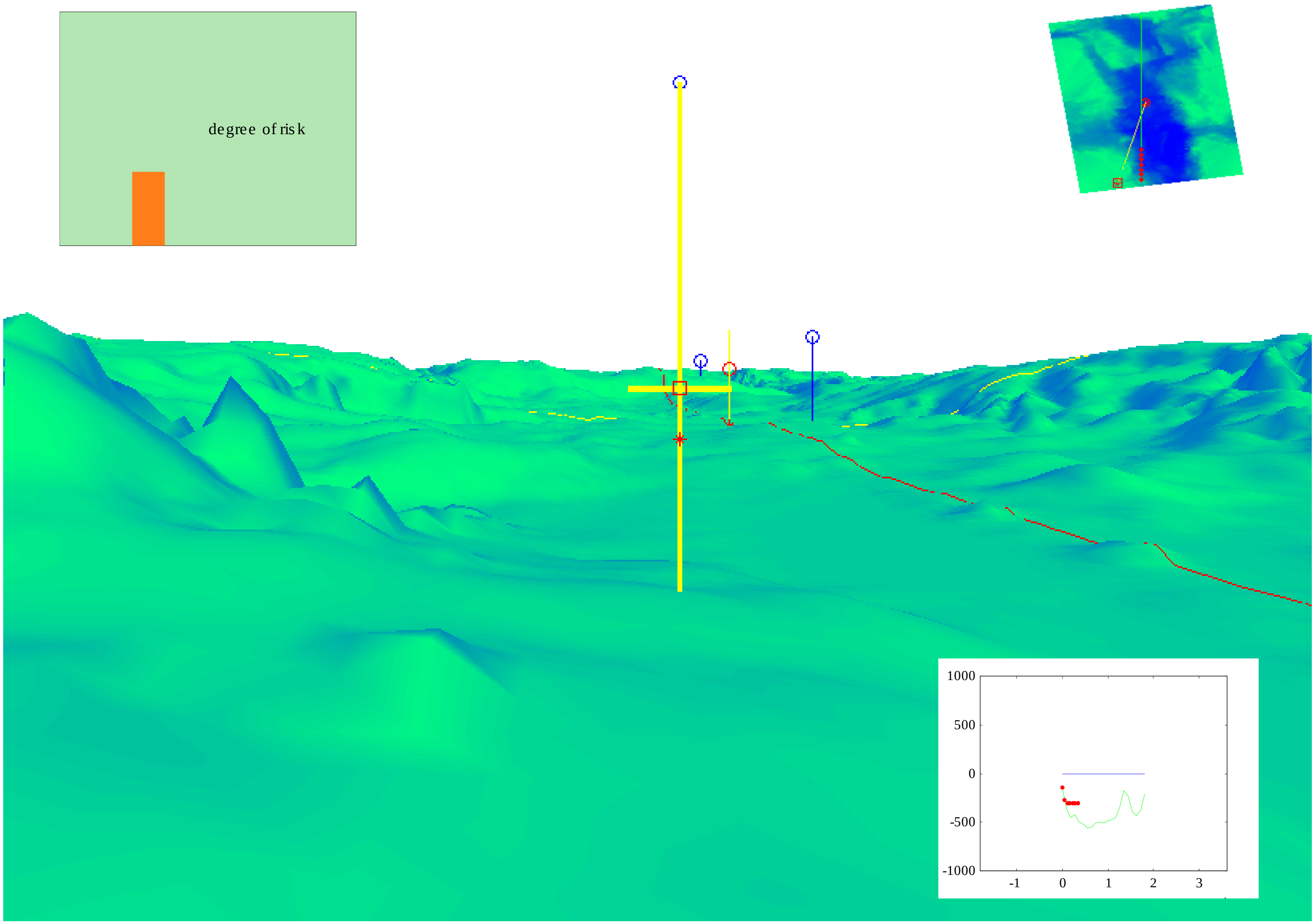
degree of risk
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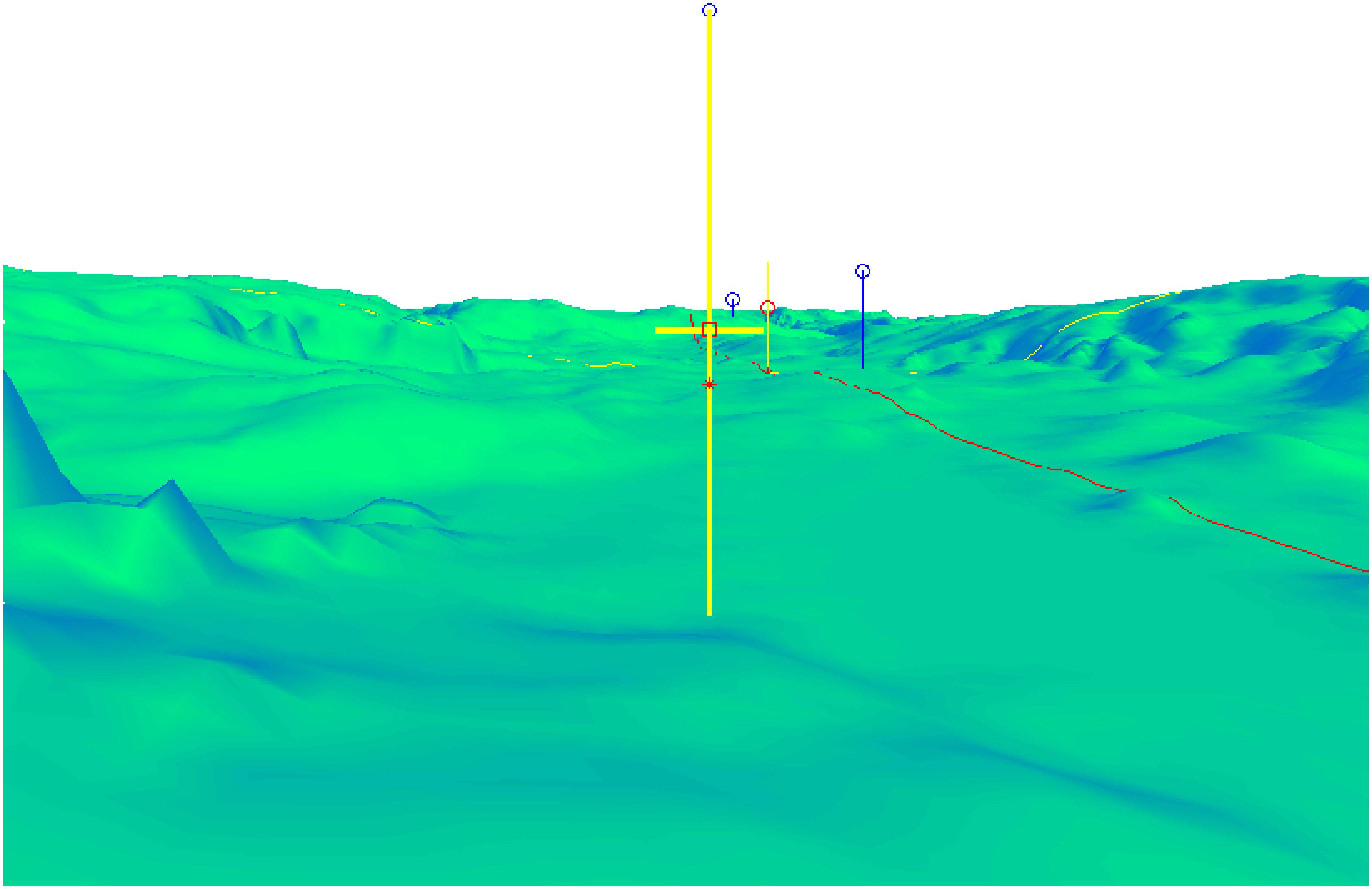

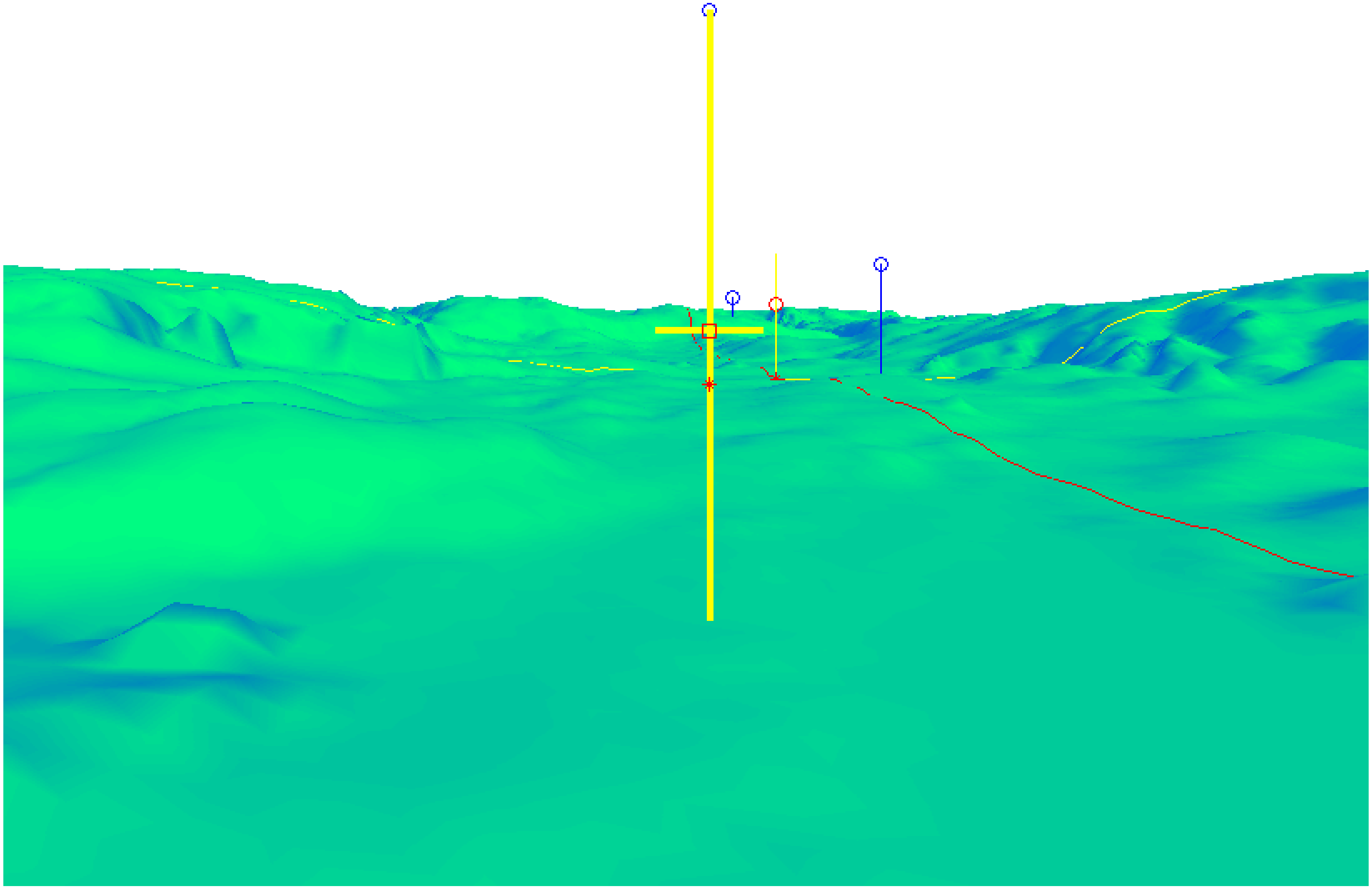

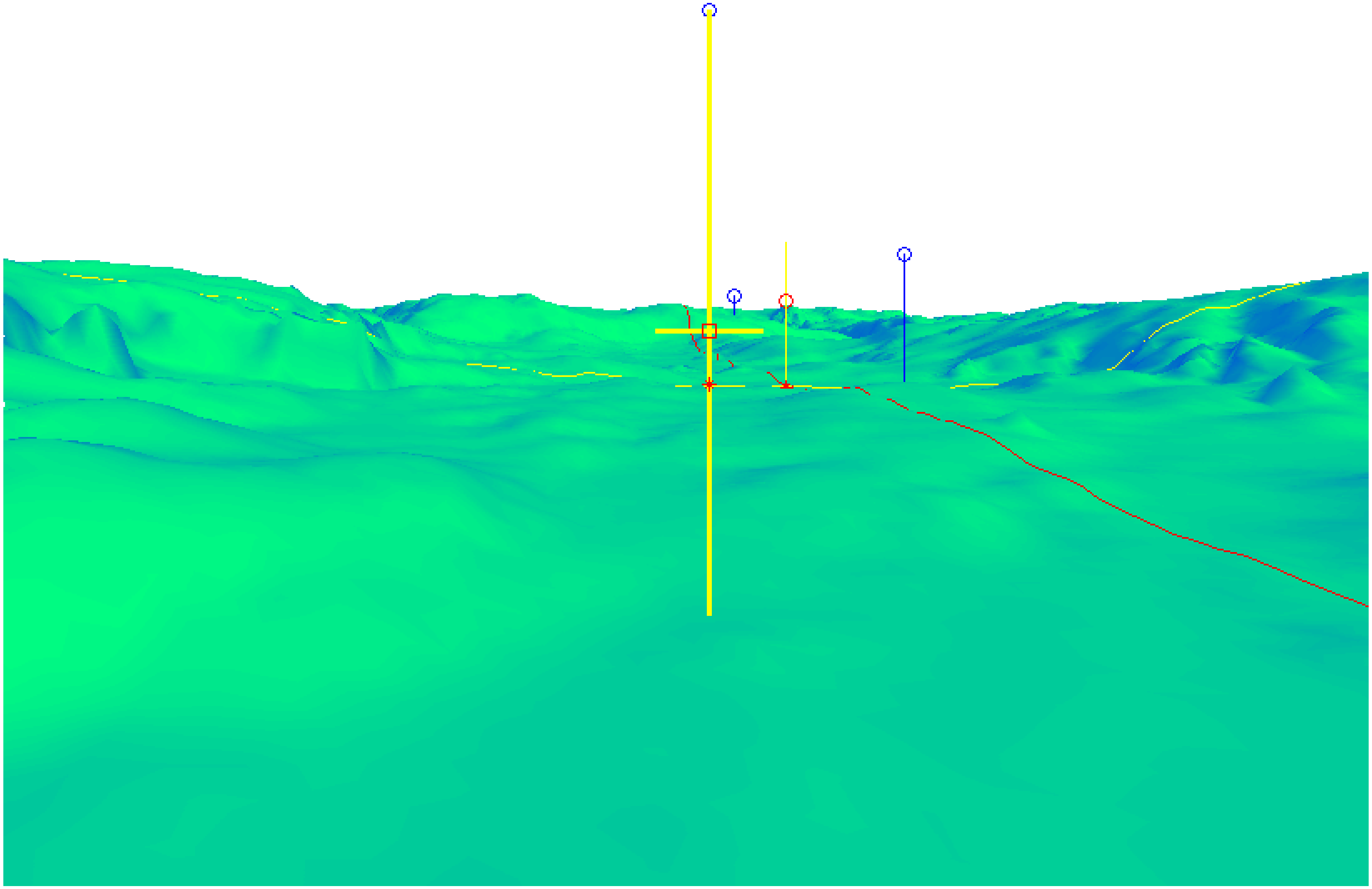

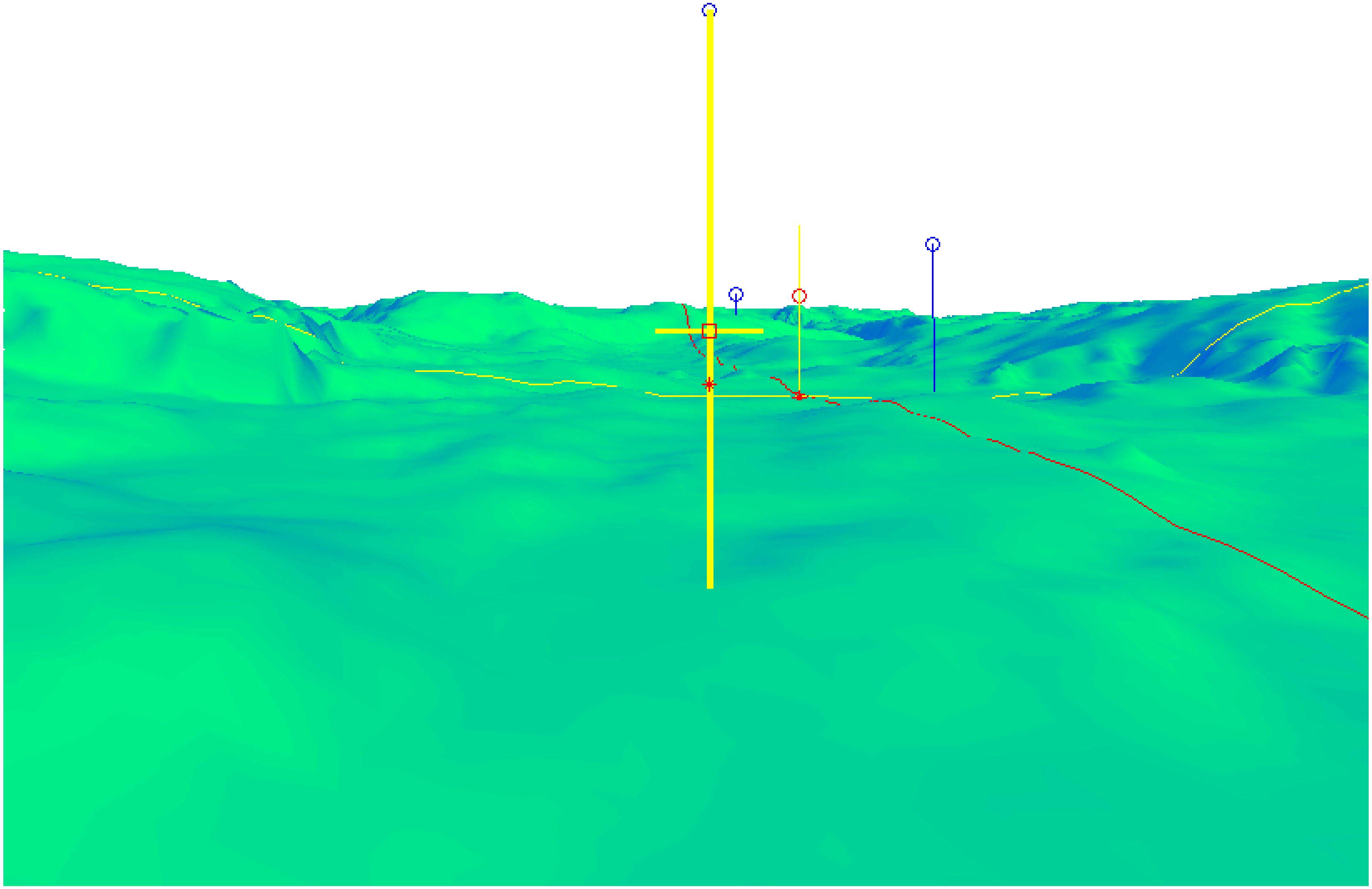

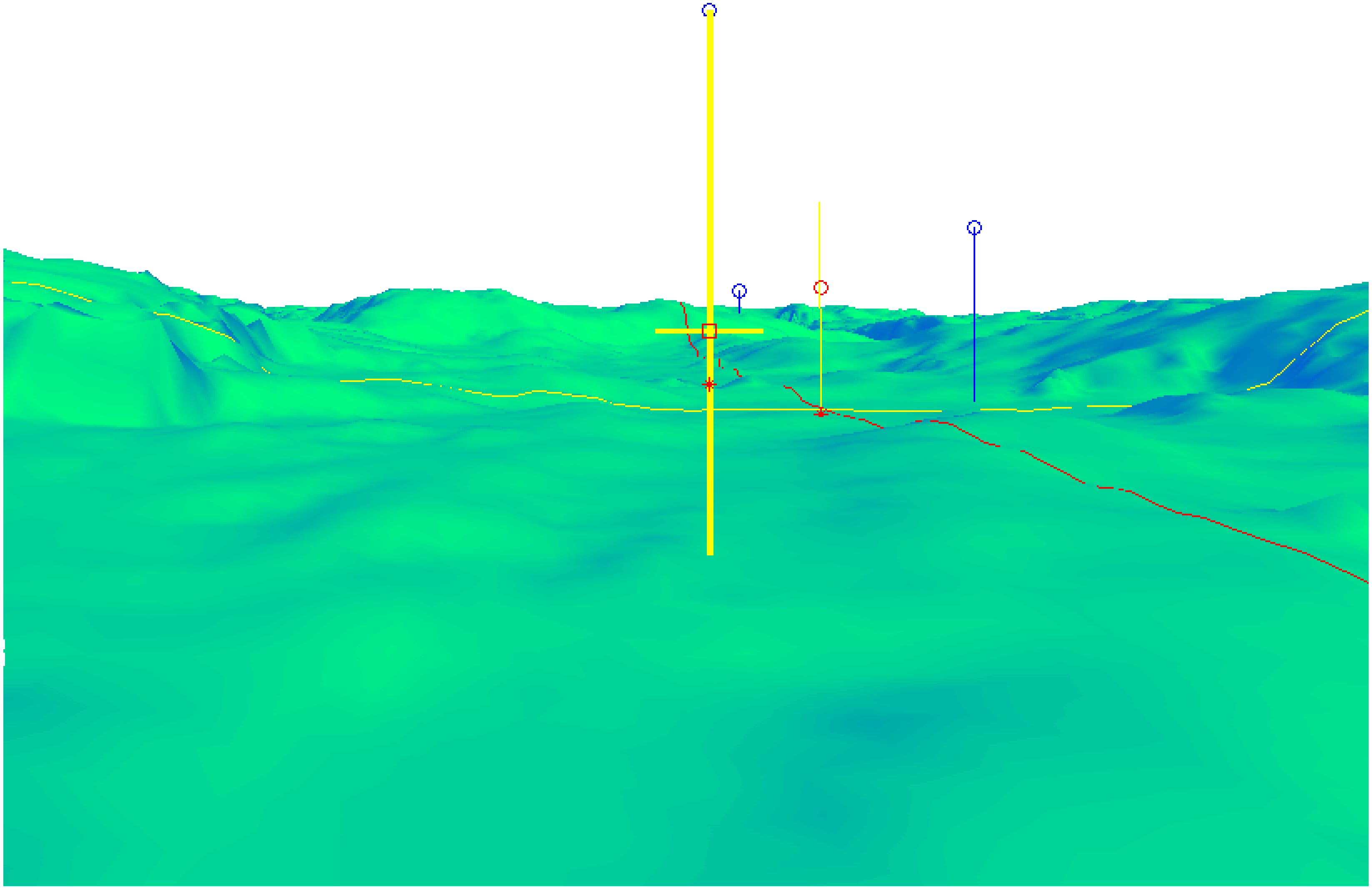

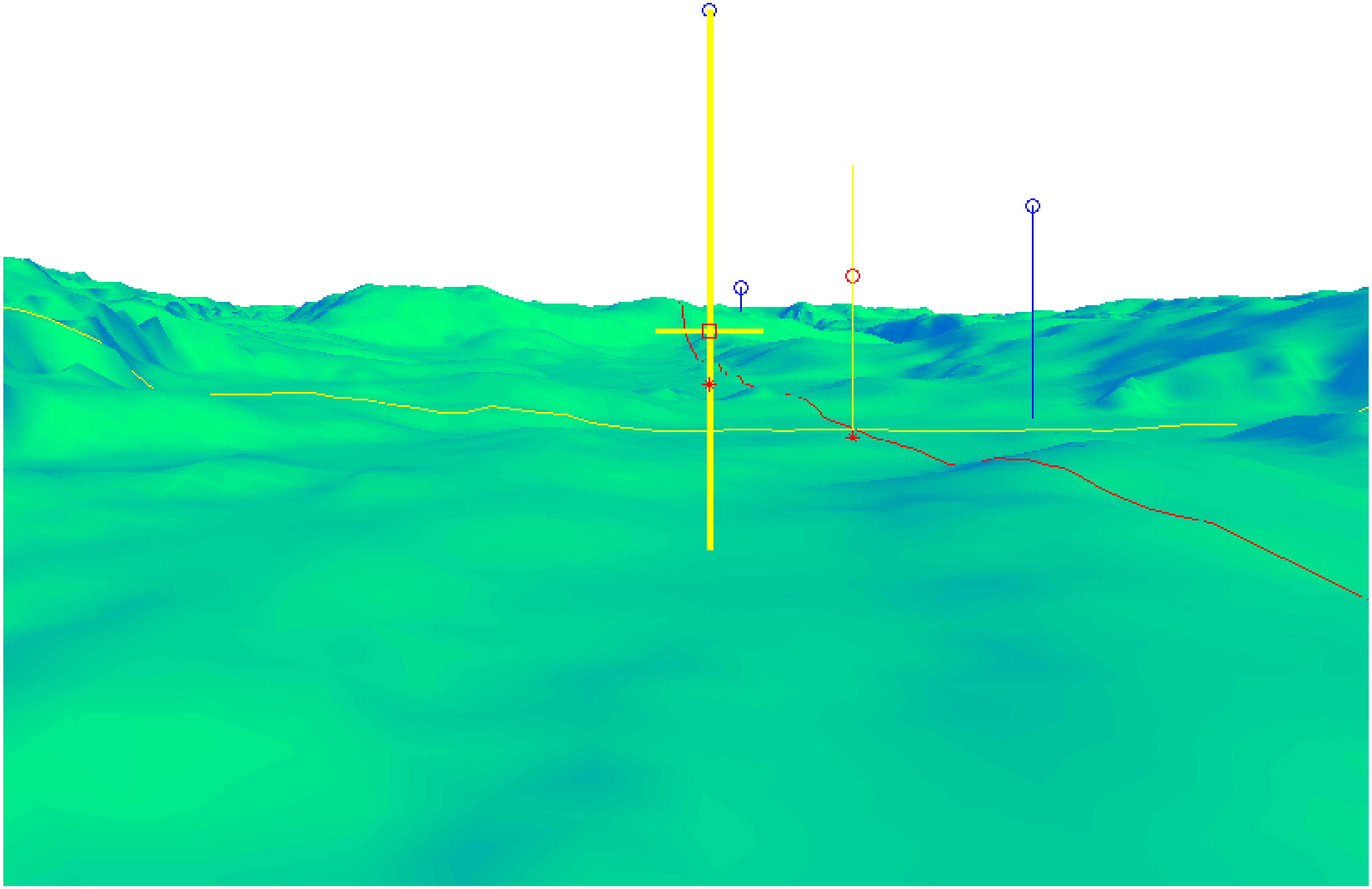

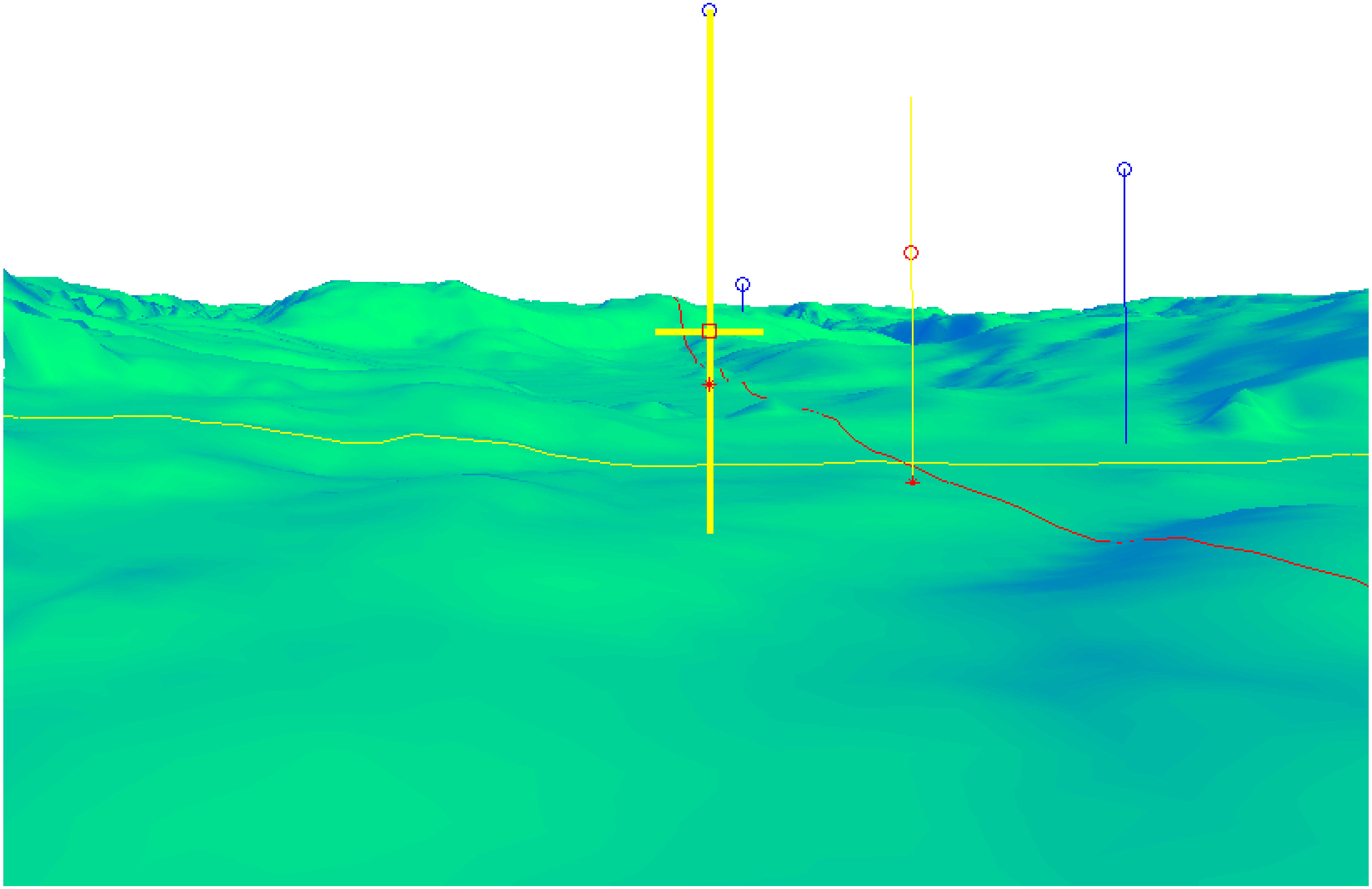

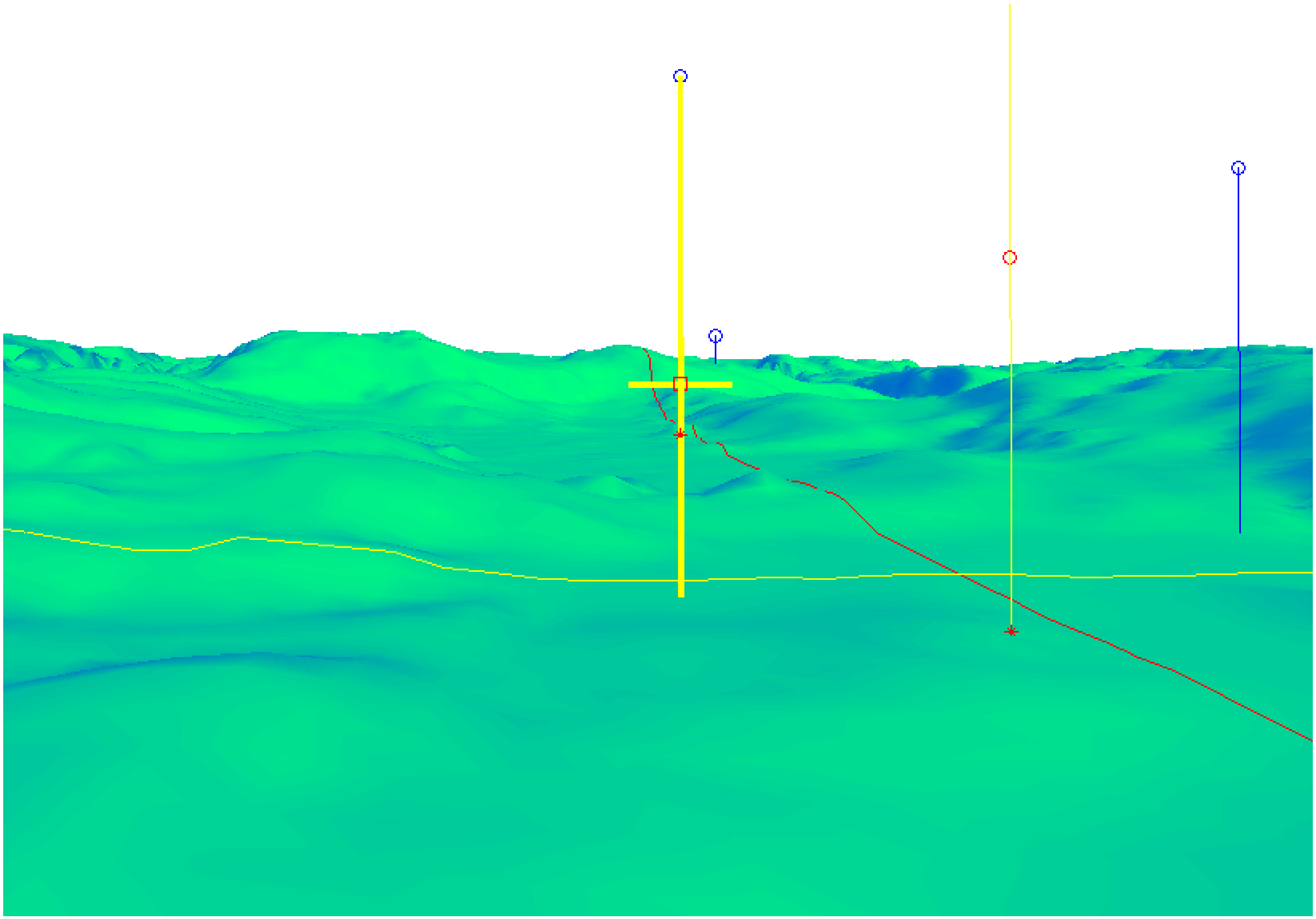

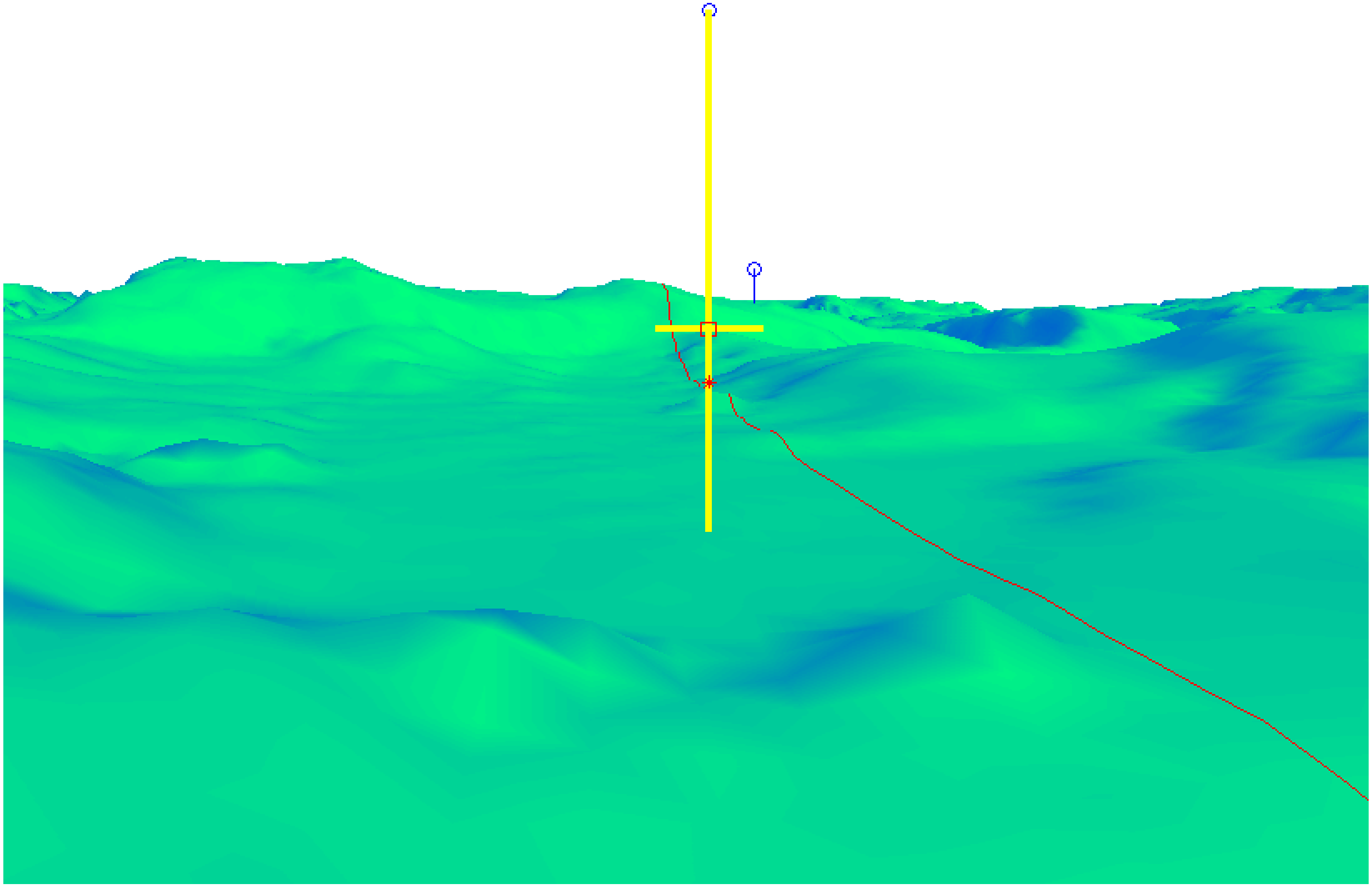

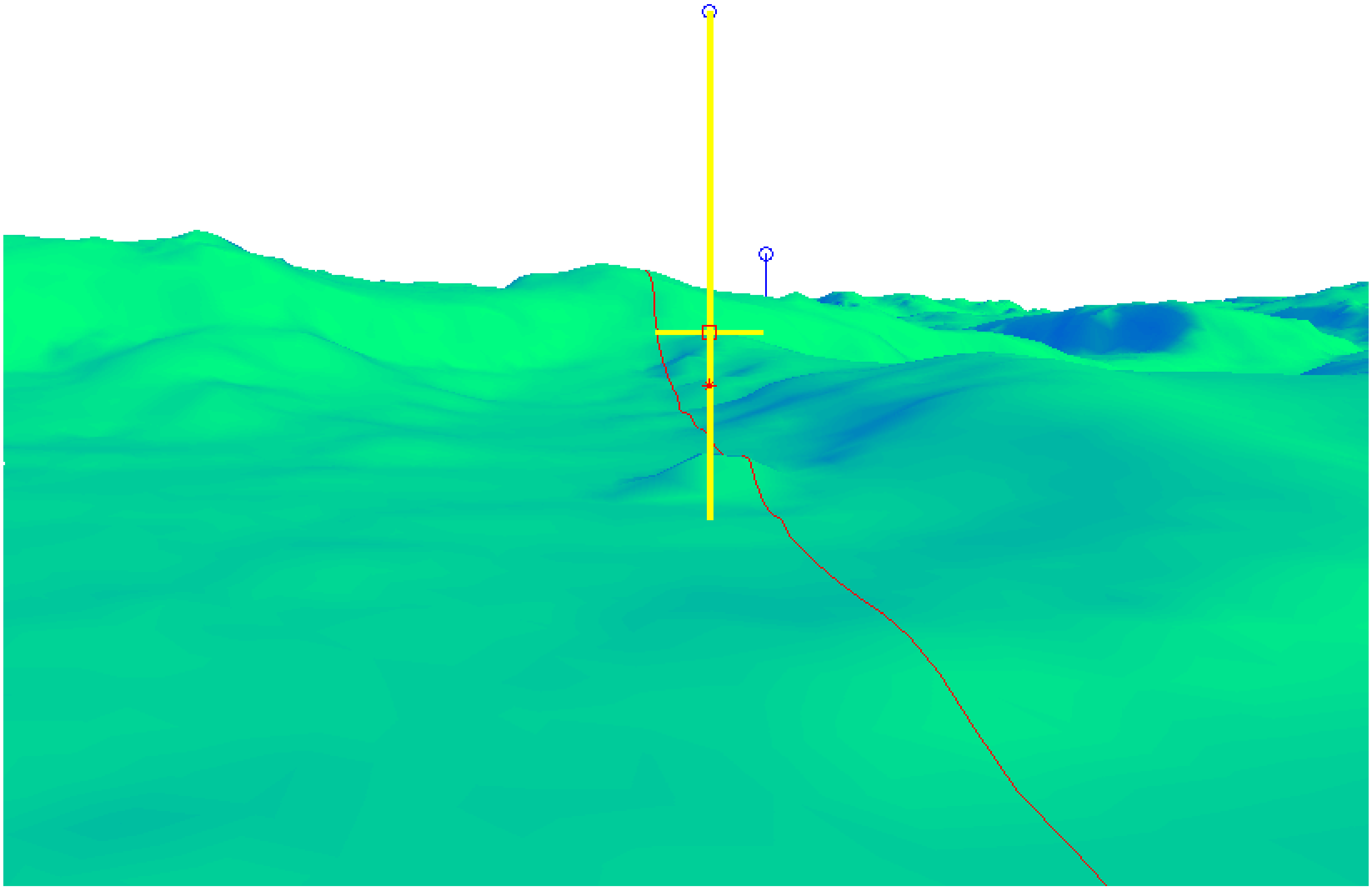

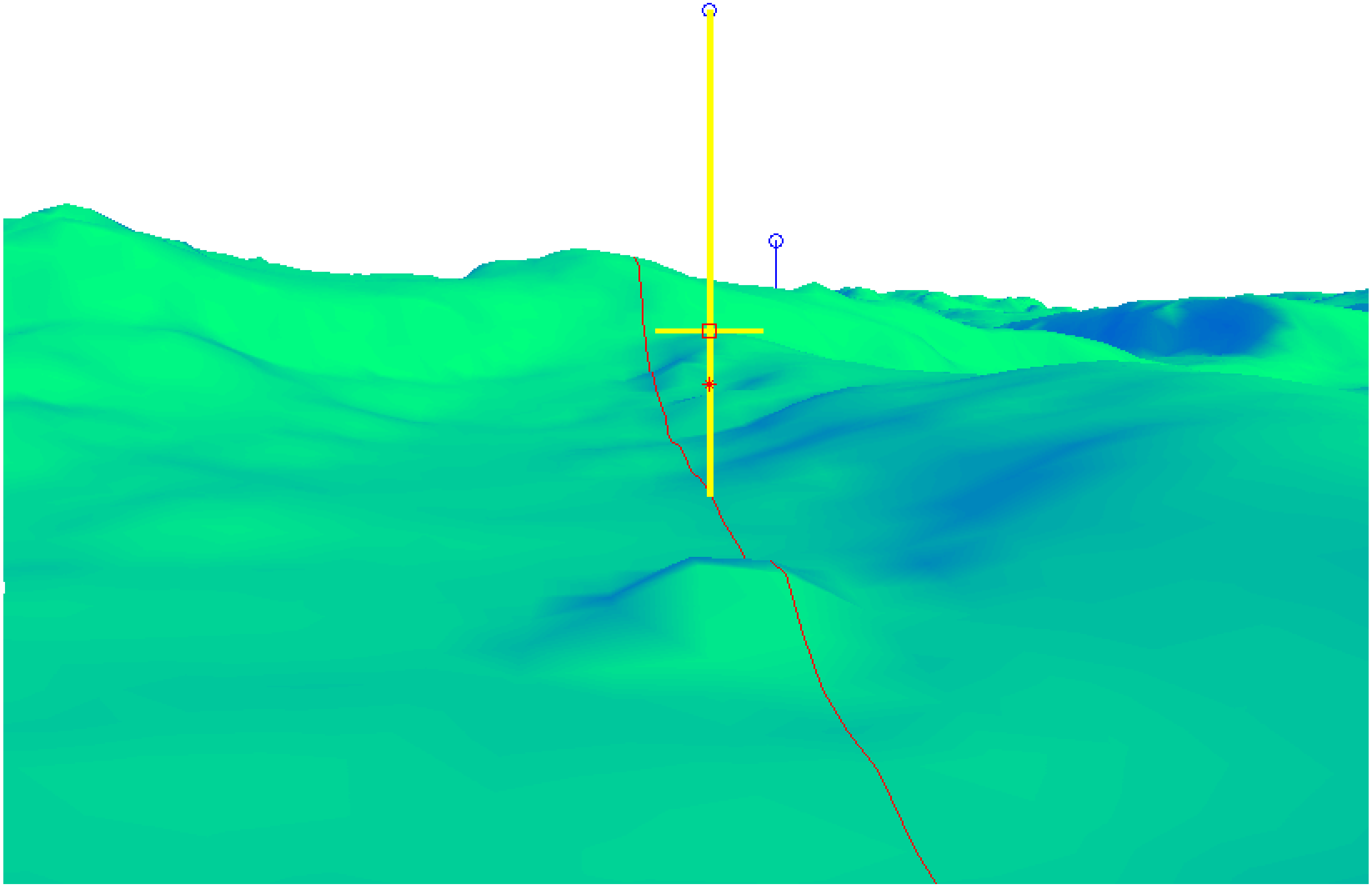

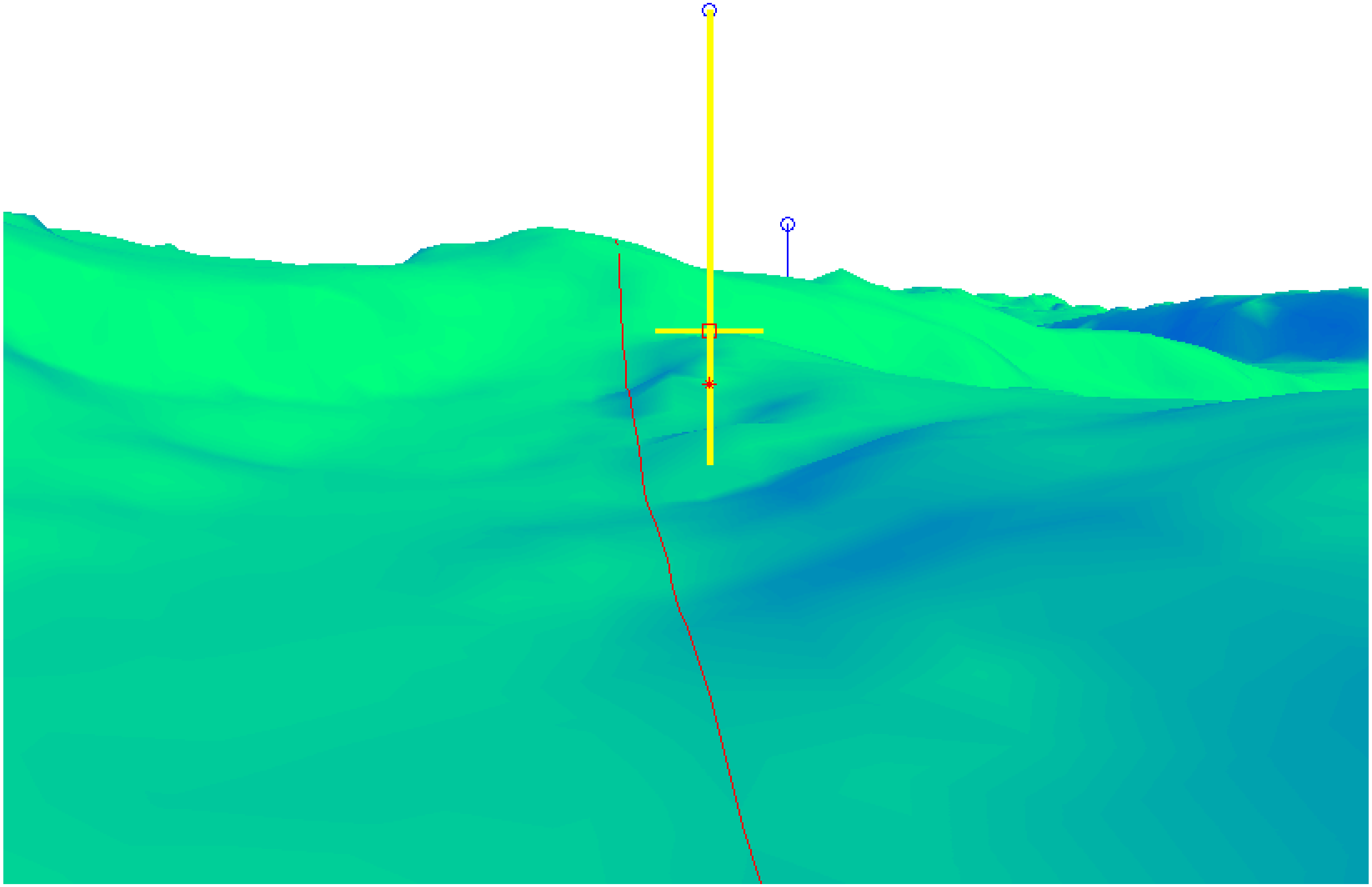

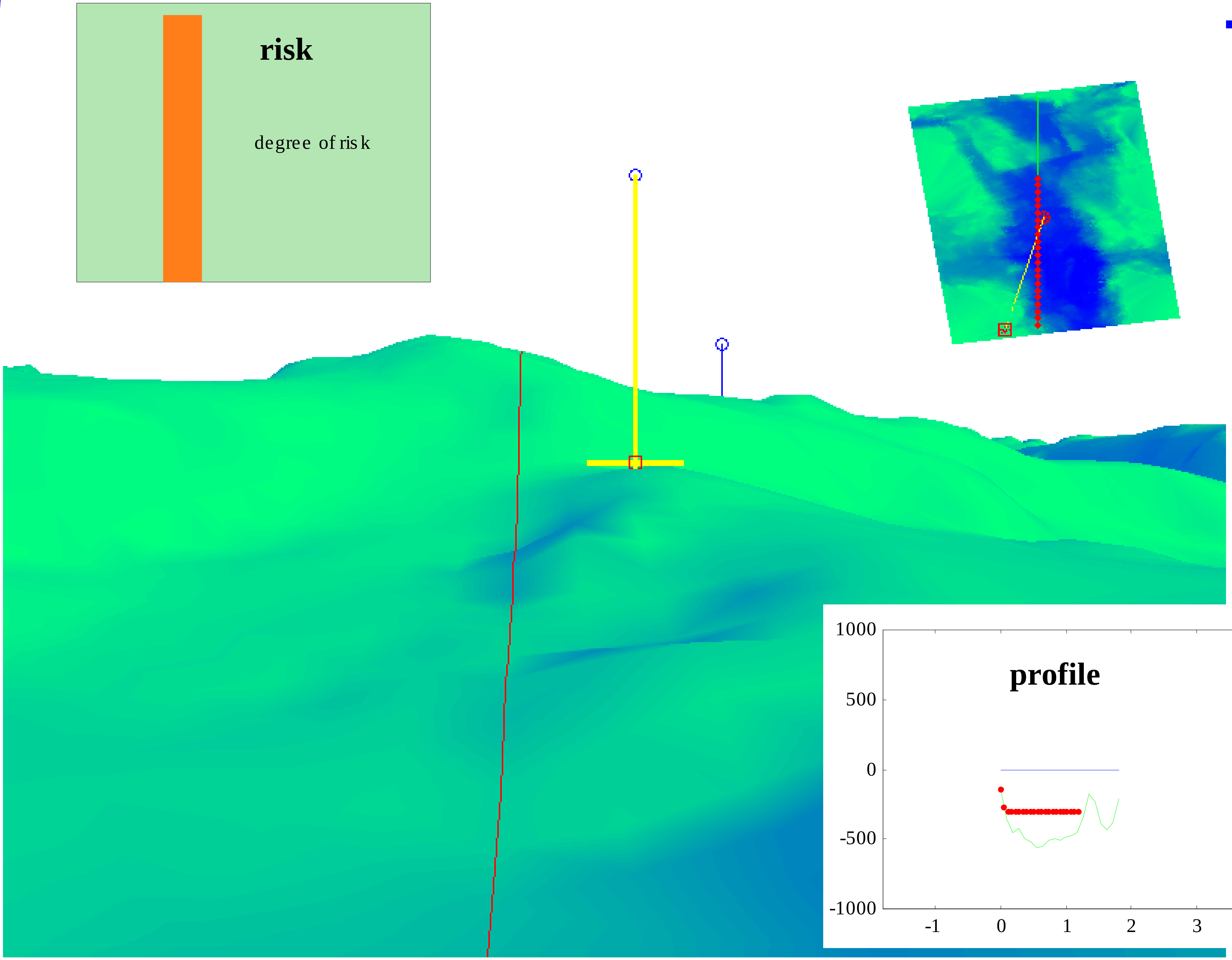
risk
degree of risk
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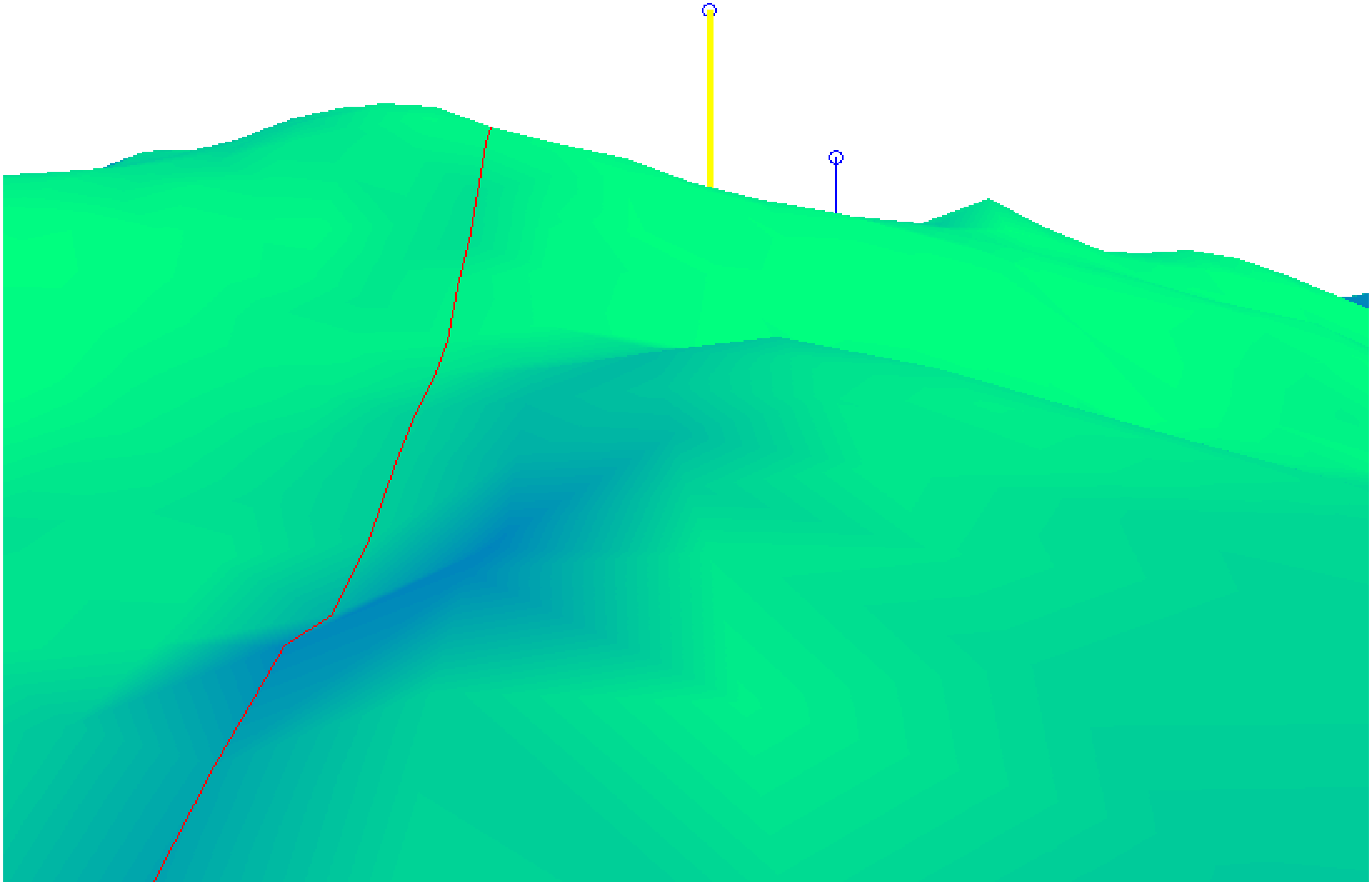
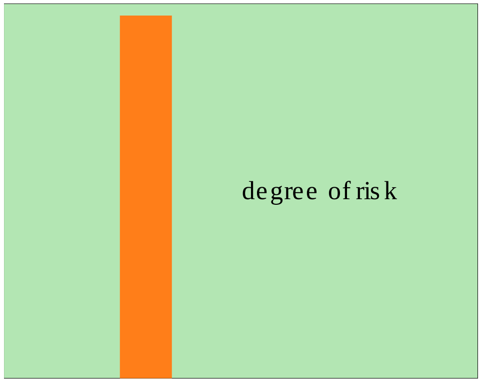
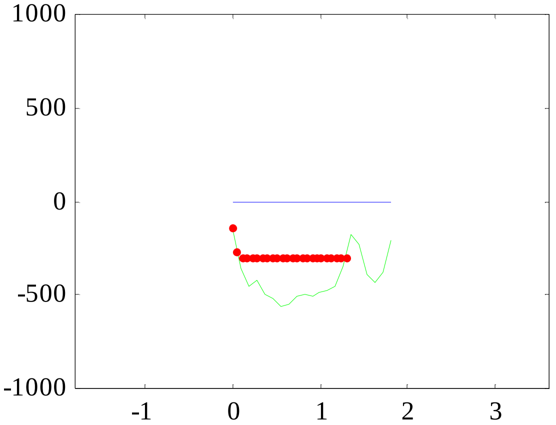



degree of risk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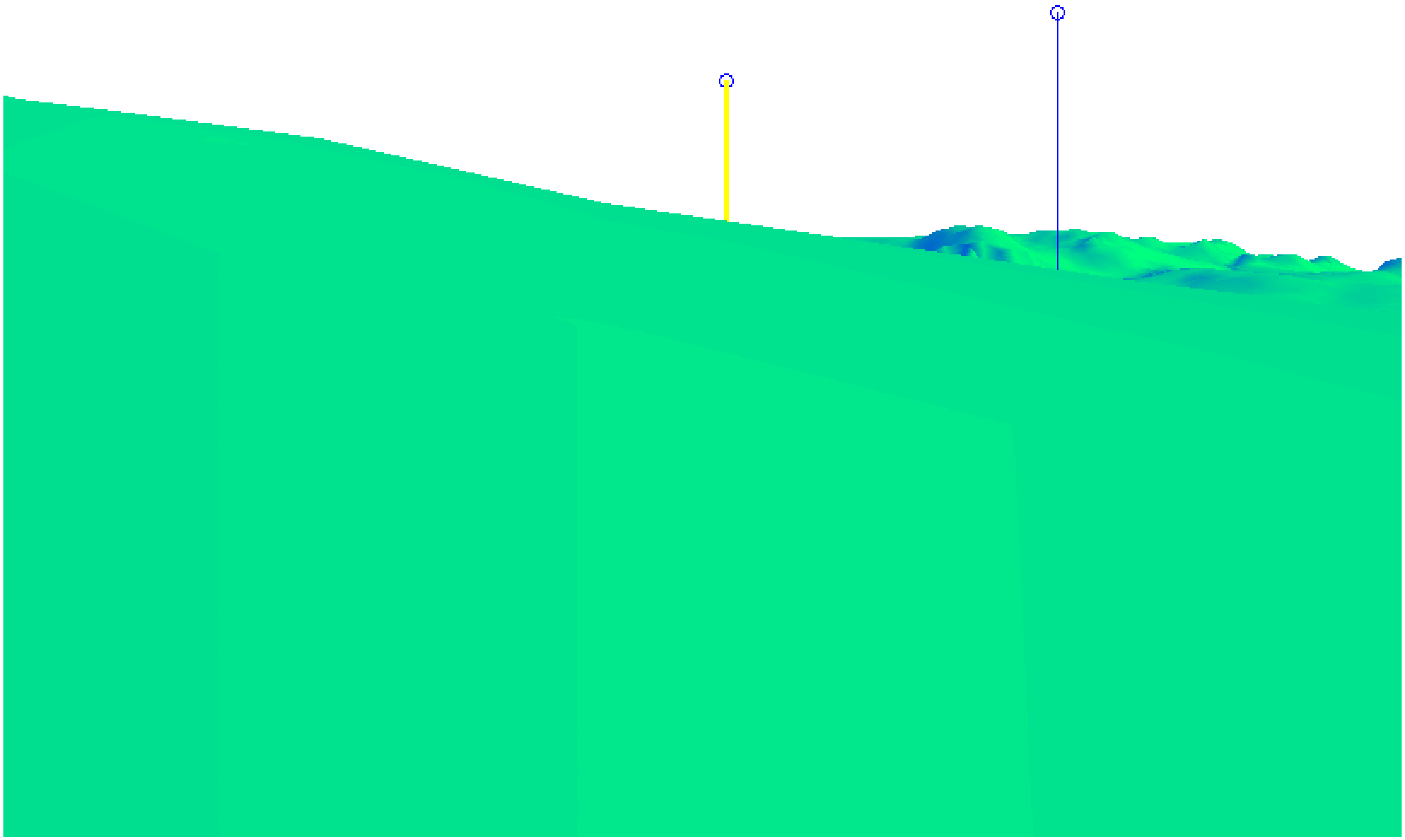
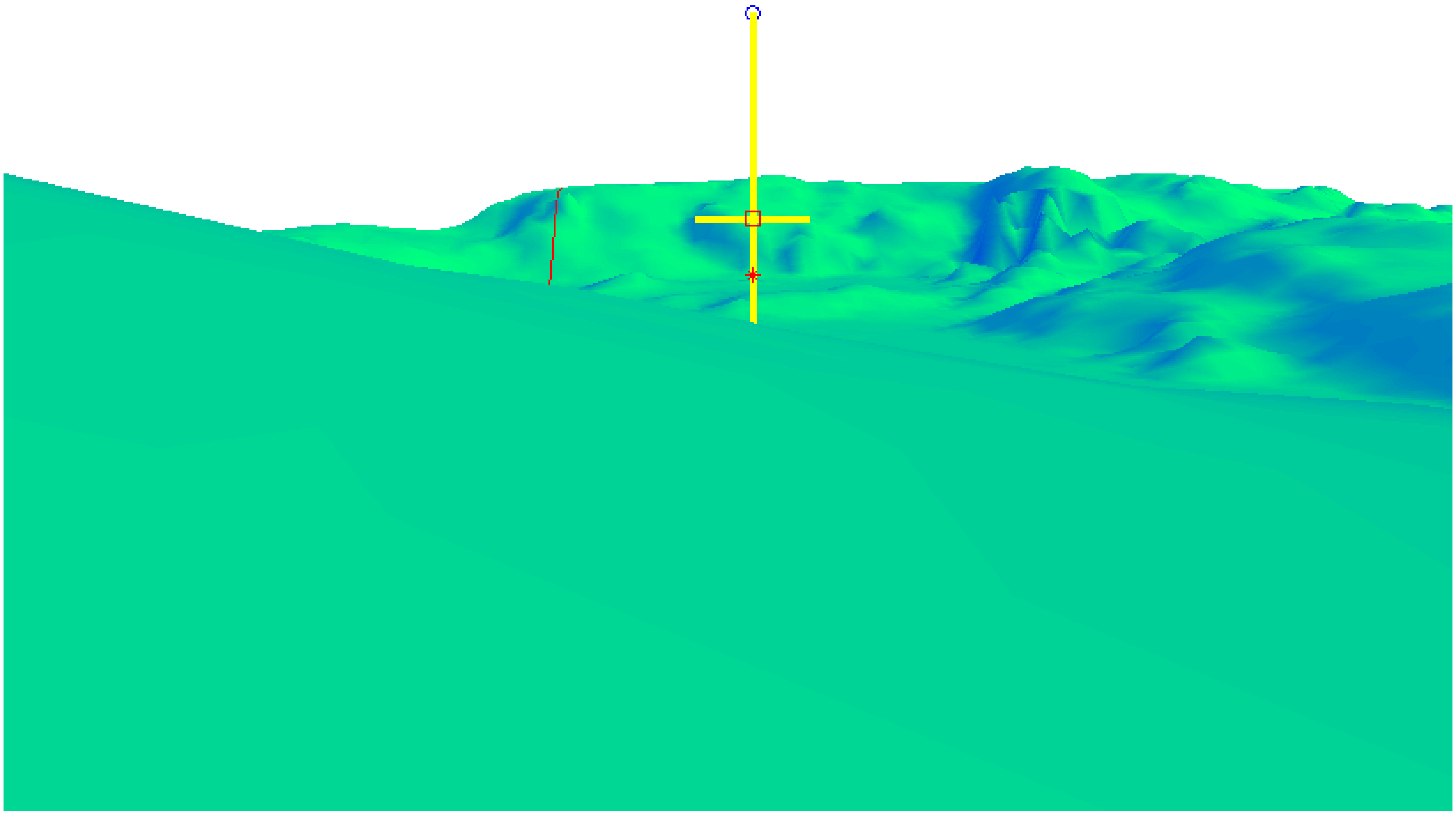
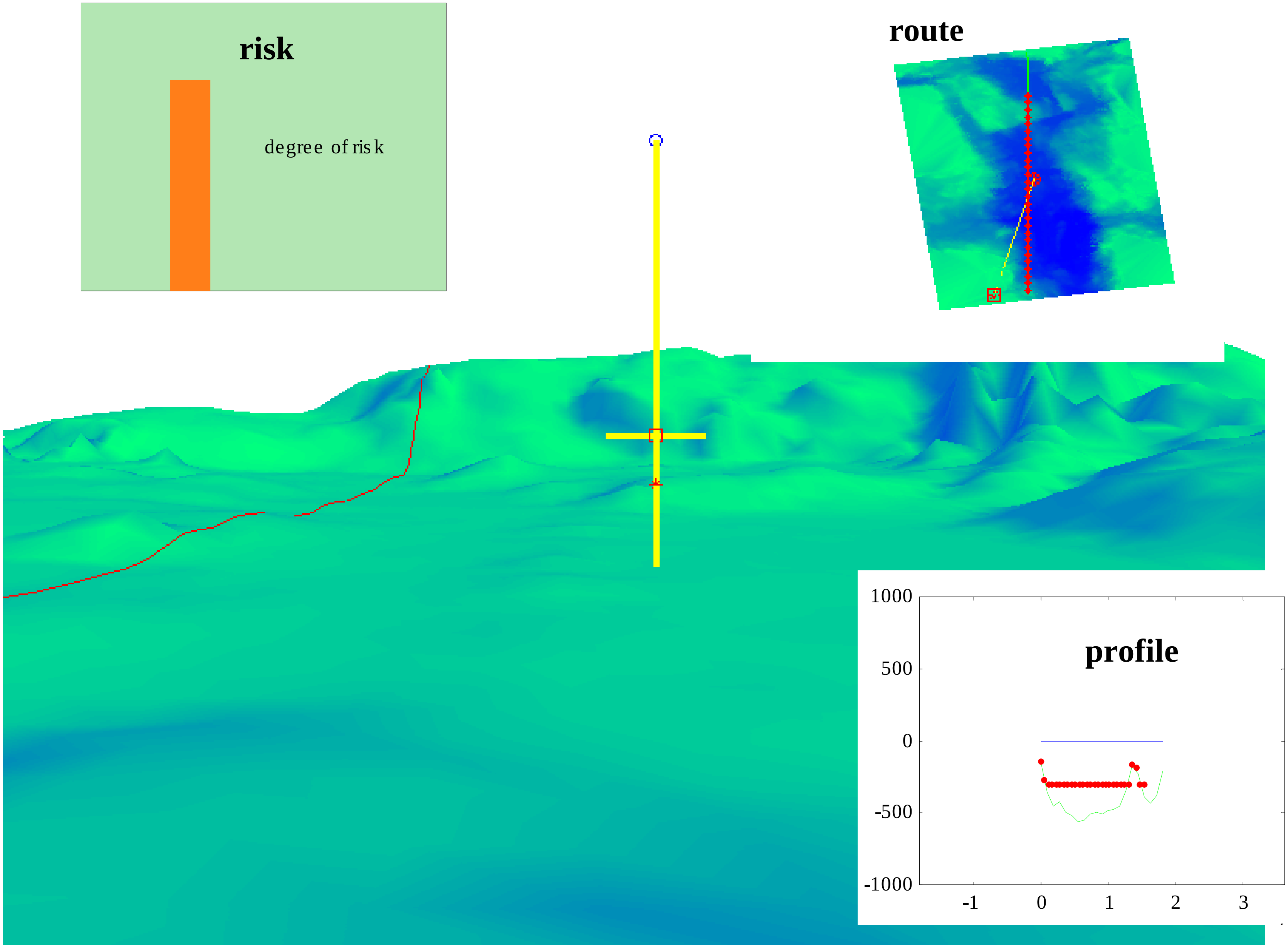
3






risk
degree of risk
route
profile
1000
500
0
-500
-1000
-1
0
1
2
3

Conclusion 1:
don’t overload the user with information

- **Due to the users limited perceptual properties, he/she must not be overloaded with information. This calls for generalization of the information.**

- **Transformation of information to higher level of communication, i.e., pragmatic level, can reduce the amount of information to be processed by the user, e.g., the application of BLOBs and natural language sentences.**

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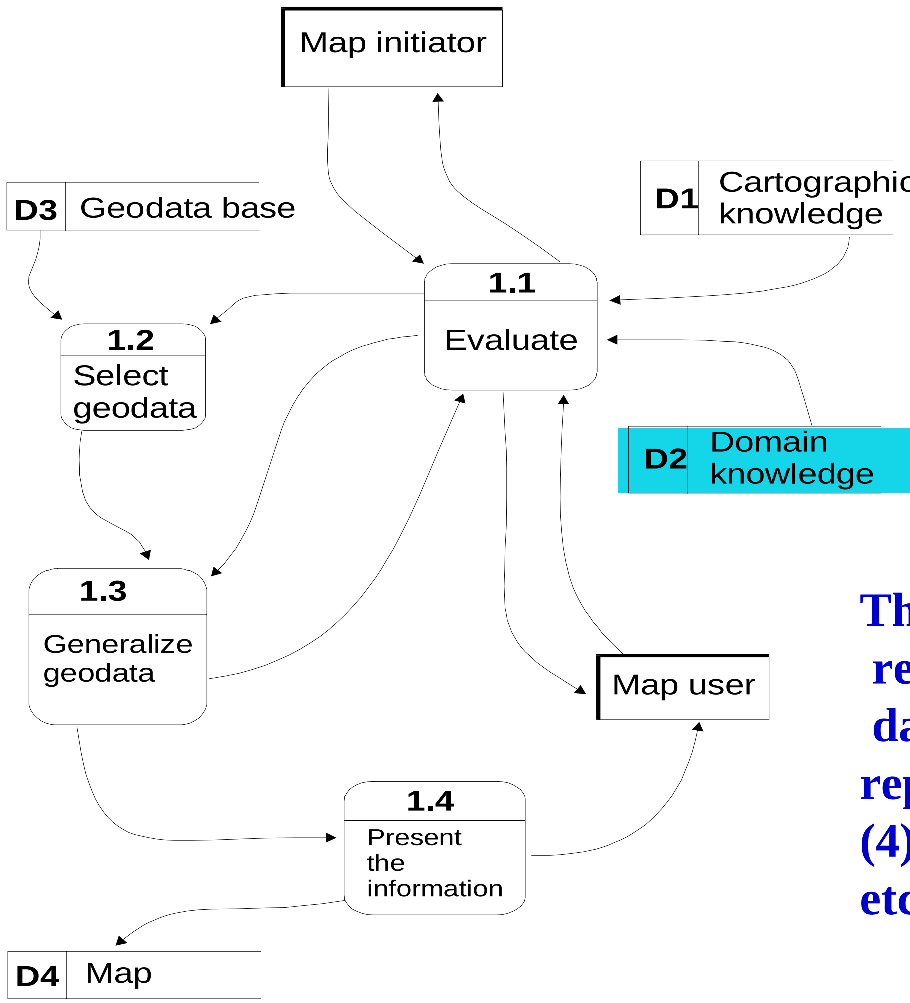
Conclusion 2: the perceptual domain has several channels



The map can be any perceptual representation of geographical data as (1) visual image, (2) iconic representation, (3) sound image, (4) natural language expression etc.etc.

Conclusion 3: the need for soft map design

- Most of the features of the real world have fuzzy boundaries and not well defined interiors. This calls for the application of soft map tools.
- Natural language sentences and iconic representations can be applied in soft map design.

Conclusion 4: Iconic representations as alternative to linguistic sentences

- Sentences like: close to, huge, large, small, meet, intersects etc. etc. can be expressed in all natural languages., i.e., we have multiple representations.

- In some cases iconic representations can solve the problem of multiple linguistic representations, i.e., the language barrier.